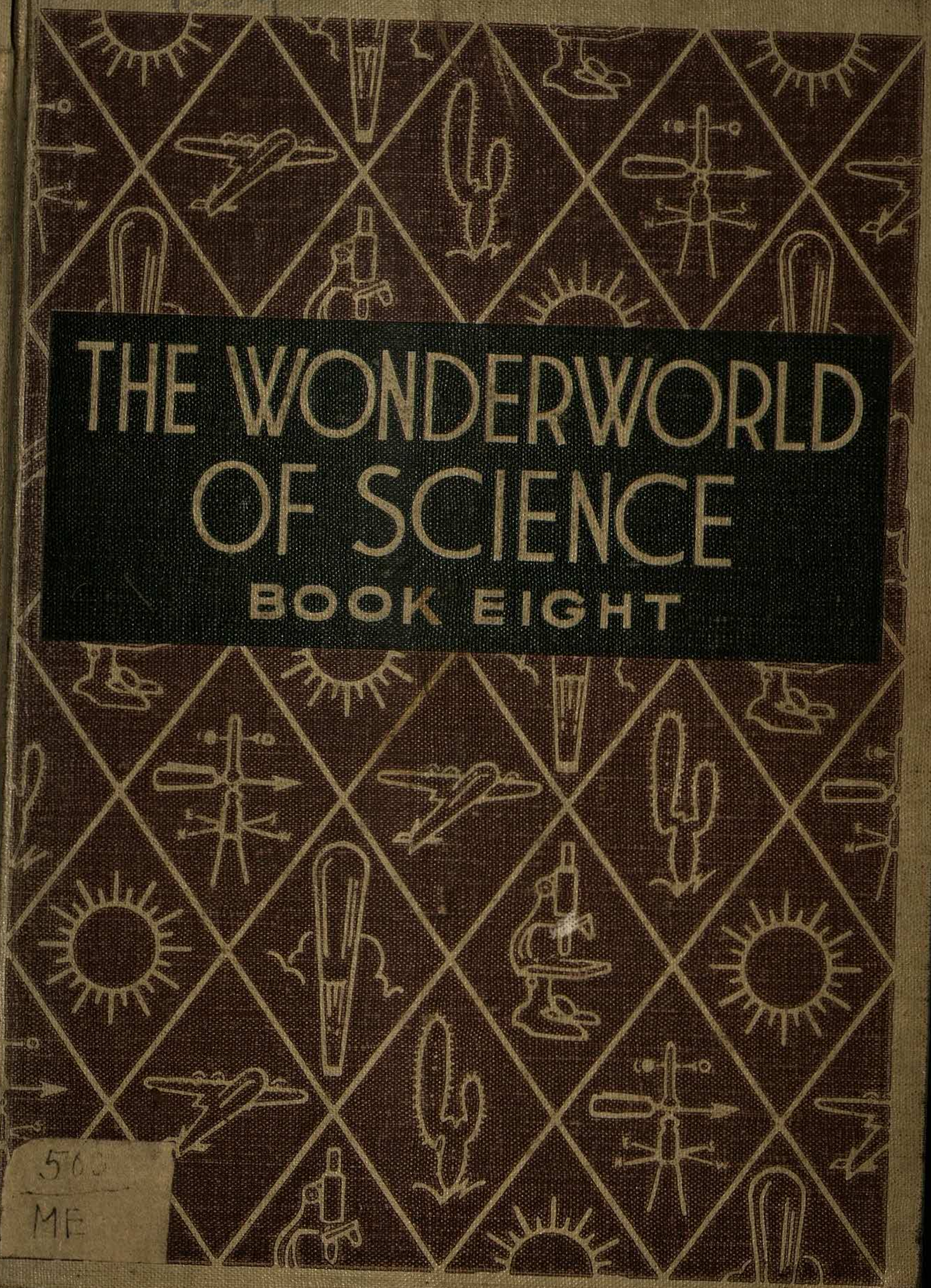
1034



THE WONDERWORLD OF SCIENCE

BOOK EIGHT

560
ME

Date Purchased__________________Copy No.______________

This book is the property of the Long Beach Unified School District and is loaned subject to the following conditions:

1. It is to be used only by the pupil to whom it is issued and is not to be transferred to another pupil.
2. It is to be retained by the pupil only as long as needed in the class for which it is issued and must be returned not later than the close of the school year or at time of withdrawal from the class if the pupil leaves before the close of the year.
3. If the book is damaged in excess of the necessary wear or if it is lost the pupil must pay a sufficient amount to cover damage or loss.
4. In case of failure to comply with above regulations, full clearance will be withheld until loss or damage is satisfactorily adjusted.

Write name and date on first blank line only.

Condition of Book	Date	Name of Pupil	Teacher
good	1/8/59	Helen Plowman	Donald F. Utter

LBSrHS Form T2—150M 12-56 30680

THE WONDERWORLD OF SCIENCE

Book Eight

500
MEI

2 copies.

By

MORRIS MEISTER
RALPH E. KEIRSTEAD
LOIS M. SHOEMAKER

CARL D. DUNCAN
Educational Consultant

INSTITUTE OF EDUCATION FOR WOMEN
April, 63.
Dept. of Extension
SERVICE.
1084(1)
CALCUTTA-27

5381
PROPERTY OF
LONG BEACH UNIFIED SCHOOL DISTRICT.

CALIFORNIA STATE SERIES
Published by CALIFORNIA STATE DEPARTMENT OF EDUCATION
Sacramento, 1952

COPYRIGHT, 1944, 1947, 1950, 1952, BY CHARLES SCRIBNER'S SONS

Illustrated by ALMA FRODERSTROM
and THOMAS VOTER

printed in
CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO 2ND PRINT, 30M 1954

CONTENTS

THE SOLAR SYSTEM

Our Neighbors in Space 7
The Earth and the Moon 22
Energy from the Sun 35
    Things to Do 47
    How Much Do I Remember? 48
    Problem Pictures 49

THE SURFACE OF THE EARTH

The Changing Face of the Earth 53
Changes in the Rocks 68
The Record in the Rocks 83
The Changing Soil 97
Minerals 111
    Things to Do 123
    How Much Do I Remember? 124
    Problem Pictures 125

THE CONTINUITY OF LIFE

The Many Kinds of Living Things 129
The Need for New Living Things 142
How New Plants Are Produced 153
How New Animals Are Produced 166
    Things to Do 177
    How Much Do I Remember? 178
    Problem Pictures 179

ENERGY FOR A WORLD AT WORK

Pushes and Pulls 183
Little Forces into Big Ones 198
Work and Energy 214
    Things to Do 229
    How Much Do I Remember? 230
    Problem Pictures 231

ENERGY FOR TRANSPORTATION

Moving Things from Place to Place 235
Across the Land 247
Over the Water 259
Through the Air 271
    Things to Do 285
    How Much Do I Remember? 286
    Problem Pictures 287

ENERGY FOR COMMUNICATION

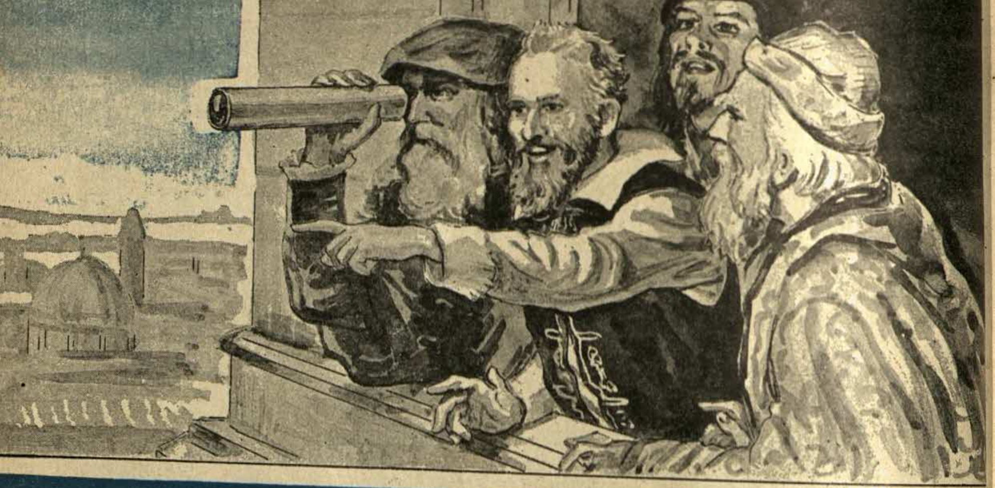
Speaking and Hearing 291
Light for Seeing 306
Messages by Electricity 322
    Things to Do 341
    How Much Do I Remember? 342
    Problem Pictures 343
ATOMIC ENERGY FOR BETTER HEALTH 345
GLOSSARY 353
INDEX 357

THE SOLAR SYSTEM

Our Neighbors in Space

It was one o'clock in the morning of January 7, 1610 Galileo Galilei stood at his attic window pointing a tube at various parts of the sky. The night was so cold that he shivered and shifted from one foot to the other, but he did not seem to be aware that he was uncomfortable. No wonder! Galileo was seeing things in the heavens that no man had ever seen before.

Galileo was an Italian, a professor at the University of Padua in Italy. A few months before he had made a telescope. For weeks, he had spent every starlit night in his attic room studying the heavens. He had discovered that the Milky Way was made up of thousands upon thousands of stars that no one had believed were there. He had seen great round pits and high mountains on the surface of the moon. The other scientists of his



time thought that all the stars had been discovered, that there could be nothing new. Yet, with this new invention he could see dozens of stars that were not visible to the naked eye.

On this morning of January 7, 1610, he stood pointing his telescope at the planet Jupiter. Suddenly he gave a sharp cry. Could it be? He rubbed his eyes. Yes, there were three bright points of light near Jupiter. No one had ever seen these before. He quickly drew a sketch of their positions. For a week he studied them. One night he saw only two. What had become of the third? On the next night, one of the two seemed larger. Then the third point of light appeared again but in a different position. One night he saw four. As he watched them hour after hour, he realized that these new bodies were revolving around Jupiter. Galileo could scarcely keep from shouting with joy. He knew that he had made a discovery of great importance. Galileo had discovered some of the moons of Jupiter.

What are the earth's neighbors in space?

On a clear night we can see more than a thousand stars. With a pair of field glasses or a small telescope, we can see many more. With the largest telescopes, millions of stars are visible. Thus we know that the earth is a tiny part of a very large universe.

The earth is one of a group of heavenly bodies that make up the solar system. The sun is the largest object in the solar system. It gives off energy in the form of heat and light. For this reason it is called a star. All of the other bodies of the solar system revolve around the sun. The paths that they travel are called *orbits*. These orbits are not perfect circles but ellipses of different sizes. Ellipses look like flattened circles. The nine large bodies that move about the sun are called *planets*. The word, planet, comes from a Greek word meaning "wanderer." The planets were called wanderers because they were not seen in the same places night after night while the stars seemed always to remain fixed. The planets are not stars because they do not give off heat and light. They shine because light from the sun is reflected from them.

Beginning nearest the sun, the planets are Mercury, Venus, the Earth and Mars. Mercury can be seen only shortly after sunset or shortly before sunrise. Venus is often visible as the biggest and brightest object in the heavens except the sun and the moon. It is often called the twin sister of the earth because it is similar in size

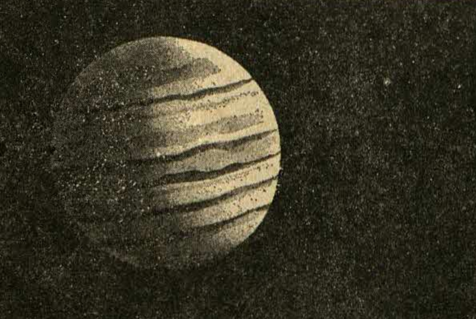
VENUS

MARS

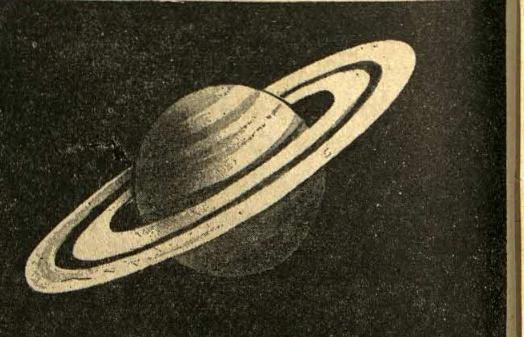
and weight and is the planet which comes closest to the earth. Mars shines with a reddish light so that it is known as the red planet.

Beyond Mars are Jupiter, Saturn, Uranus, Neptune and Pluto. Jupiter is the giant, with a weight greater than that of all the other planets together. Saturn is a beautiful sight through a telescope, for it is surrounded by bright rings. No other planet or star has been discovered which has such rings.

Neptune and Pluto are the planets most recently discovered. They are so far from the earth that they cannot be seen without a telescope. Uranus, a planet sometimes faintly visible to the naked eye, was discovered in 1781, Neptune in 1846 and Pluto in 1930. We cannot be sure that no other planets will ever be found.



JUPITER



SATURN

FACTS ABOUT THE SOLAR SYSTEM

Planets	Approximate distance from sun in miles	Diameter in miles	Approximate time for one revolution	Number of moons
Mercury	36,000,000	3,009	88 days	0
Venus	67,000,000	7,575	225 "	0
Earth	93,000,000	7,918	365 "	1
Mars	141,000,000	4,216	687 "	2
Jupiter	483,000,000	86,728	12 years	11
Saturn	886,000,000	72,430	29.5 "	9
Uranus	1,782,000,000	30,878	84 "	4
Neptune	2,793,000,000	32,932	165 "	1
Pluto	3,680,000,000	?	249 "	0

Most of us think of a thousand miles as a long distance. We are used to living on the earth, which is about 25,000 miles in circumference. When we learn of the great distances between the planets and stars, we cannot comprehend them, for we have no distances on the earth which compare with them. We may be able to get an idea of the immense distances in the solar system by going on an imaginary journey. Let us start from the sun in a machine which travels one thousand miles an hour. It takes us over four years to reach Mercury and more than ten years to reach the earth. To fly to Pluto from the sun requires 420 years.

Several of the planets have smaller bodies which revolve around them. These are called moons, or *satellites.* The moon which revolves about the earth seems to be one of the most important bodies in the heavens. It seems large only because it is nearer to us than the others. As you will note in the table, some of the planets have several moons, while others have none.

There are a large number of tiny planets, called *asteroids,* in the solar system. Most of them revolve in the region between the orbits of Mars and Jupiter. About 1400 have been discovered. All of them together would not make a fair-sized planet.

What keeps the planets in their places?

We cannot observe the stars, the planets and the moon without being amazed at their orderly movements. We know that the sun will rise daily. We know that certain stars will be visible when the night is clear and that they will be in certain places. Astronomers, who are the scientists that study the heavenly bodies, are able to calculate to a second when the moon will rise on a given day. They can tell years in advance exactly where a planet will be on any day of the year. They can do this because all heavenly bodies move in orbits and at speeds that can be measured very exactly.

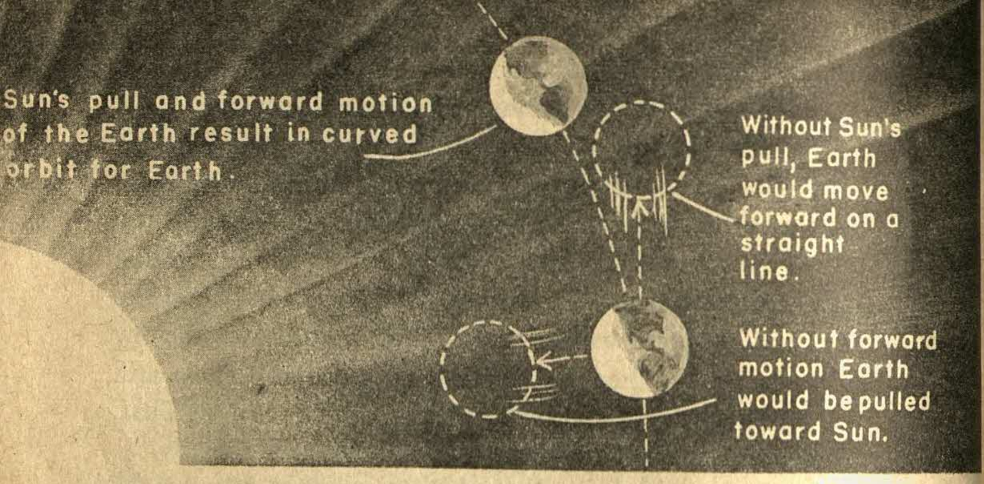
Let us now consider the ways of objects in motion. When an object of any kind is moving, it continues to move unless something stops it. The moving object cannot stop by itself. It is stopped when it strikes something or when it rubs against something. Anything that is falling stops when it hits the ground. A moving croquet ball is stopped by rubbing against the grass as it rolls along. A ping-pong ball is slowed up by rubbing against the air. This tendency of a moving object to keep on moving is called inertia of motion. Not only will a moving object keep moving, but it will move in a straight line unless some force makes it curve.

The stars and planets possess inertia because they are moving. No one can say when or how the motion started, but these bodies are moving now and we believe they will keep on moving forever unless they should collide with some other heavenly body. The spaces between the stars and planets are so great that a collision is very unlikely. Also, there is nothing between the stars and the planets, so that there is nothing to rub against. Hence, the motion does not slow down.

Inertia should keep the planets moving in straight lines. Yet we have learned that they revolve about the sun in orbits which are nearly circular ellipses. There must be some force which pulls the planets out of straight paths. To understand why this is so, let us consider some common experiences.

If we hold an object up in the air and drop it, it always falls. Even if we throw a ball as hard as we can in a straight line, it will soon curve downward until it strikes the earth. We say that the earth attracts objects. We call this force of attraction, gravity. Over two hundred years ago, a famous English scientist, Sir Isaac Newton, studied the force of gravity. He proved that there is an attraction between all objects in the universe that tends to make them move toward each other Heavy bodies attract each other more strongly than lighter ones.

The sun is about one thousand times as heavy as all the planets together. It exerts a tremendous pull on the planets. If there were no other forces acting on the

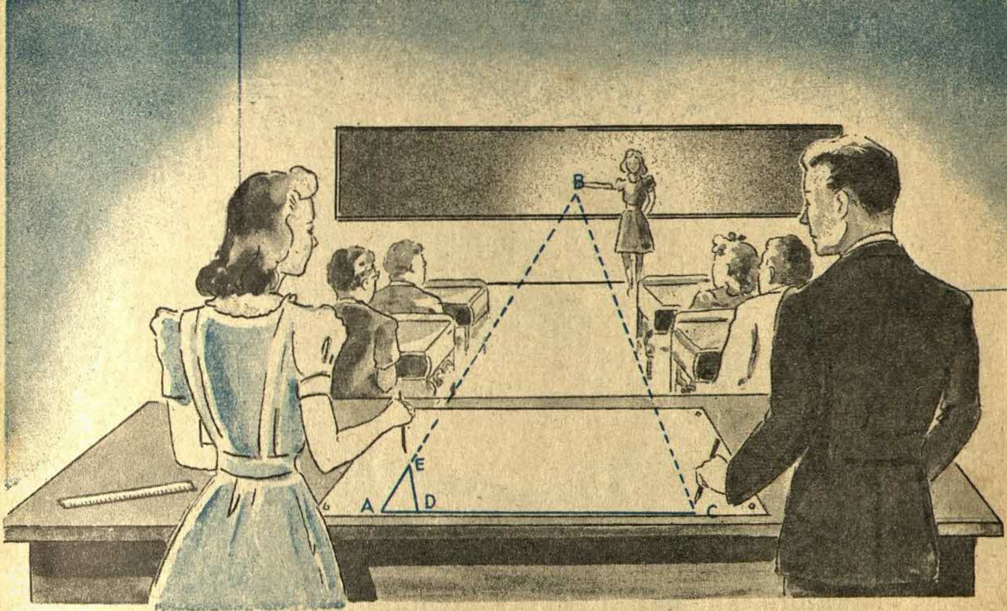

Sun's pull and forward motion of the Earth result in curved orbit for Earth.
Without Sun's pull, Earth would move forward on a straight line.
Without forward motion Earth would be pulled toward Sun.

planets, they would all move toward the sun in straight lines. However, the pull of the sun is exactly balanced by the inertia of motion of the planets and by the pull of other bodies. The combined action of inertia and gravity keeps them moving in curved paths.

What do we know about the sun?

No star has been studied as carefully as has the sun. We know that the sun is about 865,000 miles in diameter and that it is about 93,000,000 miles from the earth. How is it possible to measure these distances when we cannot actually travel to the sun?

Let us try to measure the distance from one point to another without actually stretching a tape measure between them. Place a big sheet of paper on a table at the front of your classroom. At one side of the paper mark a point A. Choose another point at the back of the room. Mark it B. In order to measure the distance between A and B, draw a long line on the paper with A



at one end. Mark the other end C. From A, sight along a ruler to point B. Draw a line along the ruler. From point C, sight along the ruler to point B. Again draw a line along the ruler. Mark a point D one-tenth of the distance from A to C. Draw a small triangle with the third side parallel to the line CB as shown in the diagram. The distance from A to B is ten times the length of the line AE. Check your answer by measuring the distance AB with a tape measure. Distances in space are measured by finding the angles at which certain heavenly bodies appear from two different points on the earth's surface. If the distance between these points is known, the distance to the star or other object can be calculated very exactly.

The sun is a very hot body. At its surface the tem-

UN AND SPOTS
CROSS SECTION OF SUN SPOT

perature is about 10,000° F., while inside the sun the temperature is believed to be several million degrees. Many elements found on the earth are also found in the sun: iron, nickel, aluminum, chromium, copper, gold and nearly fifty others. All of these are found as gases in the outer parts of the sun.

Storms occur on the sun. They are more violent than the worst tornadoes on the earth. These storms can be seen as dark areas on the sun's surface and are called *sunspots*. The number of sunspots seems to increase and decrease at fairly regular intervals. When sunspots are numerous, short-wave radio reception is upset badly.

Since the sun is very hot, it radiates heat and light in great quantities and in all directions. The earth receives about one two-billionth of this energy. Even this tiny fraction of the sun's energy would be enough to operate a hundred-thousand-horsepower engine for every per-

son on earth, if the energy could all be put to this use.

What are meteors and comets?

Have you ever seen a meteor? It is often called a shooting star. As we look into the sky on a starry night, we may see an occasional glowing object flash across the sky, leaving a fiery trail. The bright streak of light lingers for a few seconds, then is gone. Meteors are small pieces of matter which are attracted by the gravity

of the earth. They plunge into the atmosphere of the earth at a speed of twenty or more miles a second. At this great speed, they are heated by rubbing against the air and are burned up. Very few are large enough to reach the earth before they are destroyed. Meteors that reach the earth are called meteorites. There are several places where large meteors are believed to have crashed into the earth, making craters. The largest of these is in Arizona. It is almost a mile across and six hundred feet deep.

Comets are bodies, some with tails, which travel into the solar system from far out in space. Usually they are visible for only a few days or weeks as they swing around the sun and then move out into space again. Most comets are small, although there are some which are easily seen when they are near the earth. Scientists have not yet learned much about the comets. The striking thing about most of them is the glowing tail which streams out behind as the comet moves toward the sun, and which projects ahead as the comet moves away from the sun. Astronomers can predict when a comet will again come within view of the earth. For example, Halley's Comet, which appeared last in 1910, will not appear again, the scientists tell us, until 1985.

Does life exist on planets other than the earth?

There are certain planets on which we know there can be no living things such as we have on earth. Mercury is so small that its force of gravity does not attract an atmosphere. It is so near the sun that the temperature of the side facing the sun may be over 600° F. All the planets beyond Mars are so far away from the sun that they are too cold to support life. Also, the larger planets are made up mostly of gases.

Venus and Mars are the only planets on which there may be living things. Venus has an atmosphere which is always so cloudy that little has been learned about its surface. If the atmosphere of Venus is similar to that of the earth, living things may exist there.

Mars seems to have conditions somewhat like those on the earth, but its atmosphere is much thinner because this planet is much smaller than the earth. Seasons and days are similar to ours. During the spring, greenish-brown streaks appear at certain places on the surface of Mars. They remain through the summer, disappearing in autumn. Some scientists believe that these streaks are vegetation, but there are others who do not agree with this explanation. On the basis of what we now know, it cannot be said certainly that life exists on Mars. If there are living things, they must be able to live in a thinner atmosphere, at lower temperatures and in drier climates than we have on the earth.

Do we know how and when our solar system was formed?

A great many scientists have studied the solar system and have tried to explain how it was formed. Year by year, new facts have been learned; new discoveries have been made. In spite of this, we are not sure how the solar system came into being. Most scientists say that it was formed billions of years ago. They agree that the planets were once a part of the sun, for the sub-

stances found in them are the same as those in the sun.

A number of explanations have been made to account for the formation of the solar system. All these explanations are far from proved, so they are called *hypotheses*. One widely accepted hypothesis was made by two American scientists, T. C. Chamberlin and F. R. Moulton. According to them, a star passed close to the sun. The force of gravity of the star caused several waves, or tides, of gases to be torn loose from opposite sides of the sun.

As the masses were torn loose, they were affected by the gravity of both the sun and the passing star so that they swerved about in a curved path. The materials were very hot at first but they gradually cooled and condensed to form the planets as we know them today.

What are some of the heavenly bodies outside the solar system?

By means of powerful telescopes, millions of stars can be seen. Some of them are so far away that light, travelling 186,000 miles per second, takes millions of years to reach the earth. Among all these millions of stars there are many interesting things to see, but usually a good telescope is needed to study them.

Long ago it was noticed that many stars were in groups that could be recognized. Fanciful stories were written about star arrangements which seemed to resemble people or animals or other things. These groups are called *constellations*. The Big Dipper is familiar to most of us. The study of the constellations is an interesting one which can be made with the aid of star maps.

Through a telescope many hazy patches, like clouds, can be seen. These are nebulae. Some nebulae have a spiral shape. These consist of billions of stars. Other nebulae are believed to be clouds of shining gases.

All of us who have looked at the heavens have seen the bright path of stars called the Milky Way. The Milky Way is a huge disk-shaped cluster of stars of which the sun is a part. We see the cluster in edge view Such a great cluster is called a galaxy. There are many galaxies visible through the largest telescopes.

The Earth and the Moon

How would you like to explore the moon? It will have to be an imaginary trip, of course. We must plan our trip carefully, for conditions on the moon are much different from those on the earth.

We will use a rocket ship for our voyage. The ship is tightly sealed and provided with many tanks of compressed air. After we leave the earth's atmosphere, there will be no air—not even when we reach the moon, for its gravity is not enough to hold an atmosphere. Even if our rocket ship travels 1000 miles an hour, it will take ten days to cover the 240,000 miles from the earth to the moon.

All aboard! With a mighty rush we soar upward. Then we begin to see strange things. The earth gets smaller and smaller. As we watch it, we can actually see it turning. Gradually, the Atlantic Ocean sinks from view. Then Japan and China begin to appear. The stars glow brightly in the sky even though the sunlight is stronger than we have ever seen it. There is no atmosphere with its dust and moisture to scatter the light from the sun and stars. The sky between the stars appears entirely black. Soon we discover that we can walk up the sides of the rocket ship, for the gravity of the earth no longer affects us very much.

After ten days we land on the moon. What a strange place! There are no plants, no animals, no rivers, no wind, no clouds. There are tall mountains in the distance, sharp and completely barren. Since there are no winds or rains, these mountains have not been worn

down as have those on the earth. The plain on which we have landed is littered with stones of all sizes. The stones are meteorites which have fallen on the moon. There being no air, they do not burn up as they do when they fall toward the earth. As we gaze at the strange scenery, we can see meteorites hitting the surface of the plain and bouncing like hailstones.

We put on special clothing and air masks and climb out of the rocket ship. The sun's rays are unbearably hot. Outside of our clothing the temperature is 250° F., since the rays from the sun are not partly absorbed

by a layer of air as they are on the earth. We cannot talk with each other, again because there is no air. We pick up some of the meteorites and discover that they seem very light in weight. The moon is so much smaller than the earth that objects on it weigh much less than on the earth. We find that we can walk much more lightly, too. We can jump easily over rocks 20 feet high. We explore big circular depressions which look like shell holes. They are the scars left where big meteorites have crashed into the moon. We shudder to think what might happen if we were hit by a meteorite. It does not take us long to decide that the earth is a much better place to live than the dead, airless, waterless moon.

What is the cause of day and night?

The earth is like a great spinning top which turns once every 24 hours about a line connecting the North and South Poles. This line is called the axis. The period of 24 hours is a day as we note it on a calendar.

We also have another meaning for day. As the earth spins, one half is always facing the sun and receiving light and heat directly. The other half is in darkness except for starlight and reflected sunlight from the moon. The period in which sunlight is received directly is called day, and the hours of darkness, night.

Night and day follow each other in regular alternation because the earth rotates on its axis once every 24 hours. If you have ever ridden on a merry-go-round you can understand how this comes about. Suppose you are sitting on a merry-go-round, with people, cars and other objects near-by. You cannot see all of them at the same time, but as you ride around, one after another comes into view. Then you ride past each one and it is no longer visible until you come around again. If you can forget that the merry-go-round is moving, it will seem that all these objects are constantly circling about you.

The earth is like a great merry-go-round which is always carrying us toward the east. In every direction from the earth are heavenly bodies—the stars, the moon and the sun. As we go eastward, one after another appears. All of them seem to be moving constantly in a westerly direction, for the earth is so large that we are not aware that it is moving. Day is the time when, as the earth rotates, sunlight is visible; night is the time when it is not visible.

The hours of daylight and darkness are not of equal length except for a few days in the year. At the poles, a day is six months long. It is followed by a night of equal length. Between the Arctic Circle and the Antarctic Circle there are a day and a night in each 24 hours.

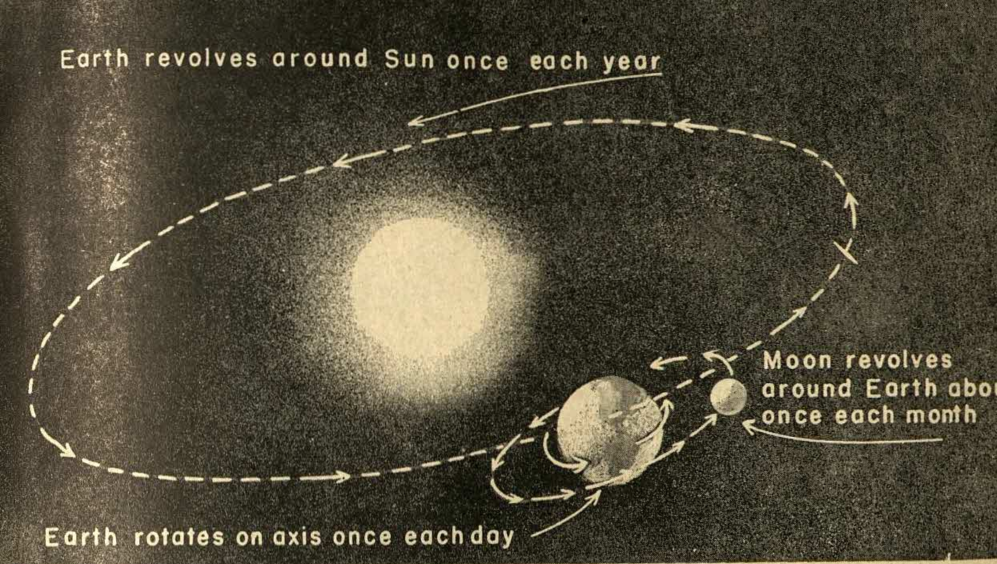
How is time measured?

No one knows how long ago people began to keep track of time. We do know that even the most uncivilized people have some way of measuring the passage of time. All methods of measuring time are based on the motion of the earth with respect to its neighbors. Thus, a year is the time of one revolution of the earth around the sun. Early peoples recognized the passage of time by the change in the seasons, which are caused by the change in the position of the earth in its orbit.

The moon gives another way of reckoning time. The moon revolves about the earth, taking about four weeks to complete one revolution. The time of a revolution of the moon is called a lunar month. American Indians measured time by the moon. Our calendar month was made a little longer than a lunar month in order that there should be no more than twelve months in a year.

The rotation of the earth gives another measure of time—the day. For example, the time from one noon to the next is a day. Not many years ago it was common for people to measure time by the position of the sun in the sky. Sundials were used. These measure time by the position of a shadow on a marked-off circle.

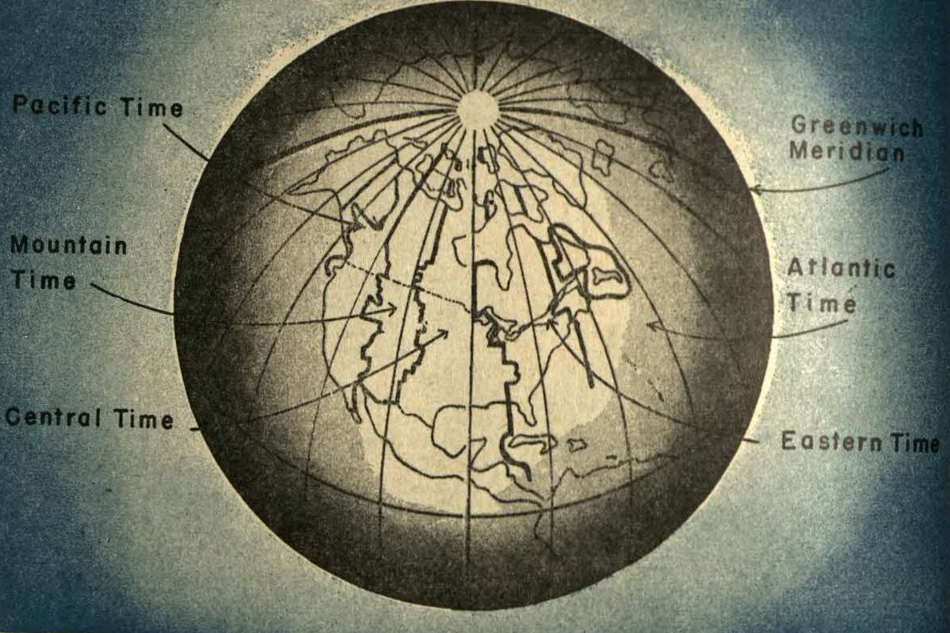
A day as measured by the sun is not always exactly the same length, since the movements of the earth and


Earth revolves around Sun once each year
Moon revolves
around Earth abo
once each month
Earth rotates on axis once each day

the sun vary slightly at different times in the year. The difference in the length of two days is never more than a few minutes, however—not enough to be of much concern to most of us.

When clocks and watches came into common use, sun time became a real nuisance because timepieces could not be made easily to measure days of different lengths. If clocks and watches are to be accurate, they must run at a regular rate day after day. Hence, a day was invented which was the same length throughout the year. This is an average day as measured by the sun. It is called a mean solar day. The time which we now use is *mean solar time*.

All places on a line running north and south have the same time, measured by the sun. For example, it is noon when the sun is directly over this line. At places east of the line it is past noon and at places west of the



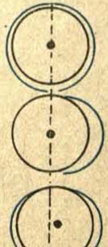
line it is not yet noon. This means that places slightly east or west of a given place have different times. In days when people travelled about very little, this was not an important matter. When railroads became numerous, however, this became a serious problem since each station then had a time which was different from all others. To solve this problem *standard time* was invented. The earth turns through a complete circle, or 360°, in 24 hours. Fifteen degrees are covered every hour. In standard time, all places in a region 15 degrees wide from east to west keep the same time. In the United States there are four of these time belts. Each one has time one hour later than the zone to its west. Thus when it is noon in New York City, it is eleven o'clock in the morning at Chicago, ten o'clock in Denver and nine o'clock in San Francisco. The map shows the time belts. Their boundaries are not straight lines, because an effort was made to keep near-by cities in the same time belt.

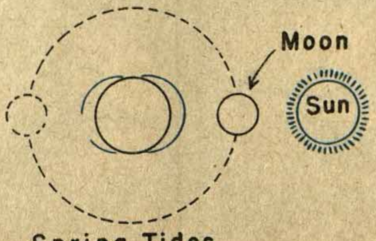
How does the movement of the moon affect the earth?

The moon makes one complete trip around the earth in a little more than 29 days. At the same time it rotates on its axis once. For this reason the same face of the moon is always turned toward the earth. No one has ever seen the other side of the moon.

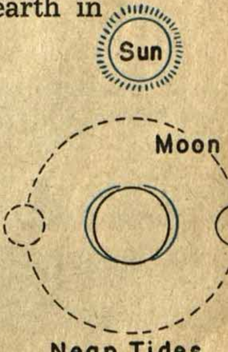
The gravity of the moon is the main cause of tides on the earth. It is easy to understand why the water on the side of the earth facing the moon is pulled to a high tide by gravity. But why should the water on the side of the earth away from the moon be at high tide at the same time? Different reasons are given. The easiest to understand is that the moon pulls the solid part of the earth as well as its water. As the solid earth moves a bit toward the moon, it leaves the water behind. Hence, there is a high tide on the side of the earth away from the moon and also a high tide on the side of the earth facing the moon. Study the drawing.

The rise of water on opposite sides of the earth in





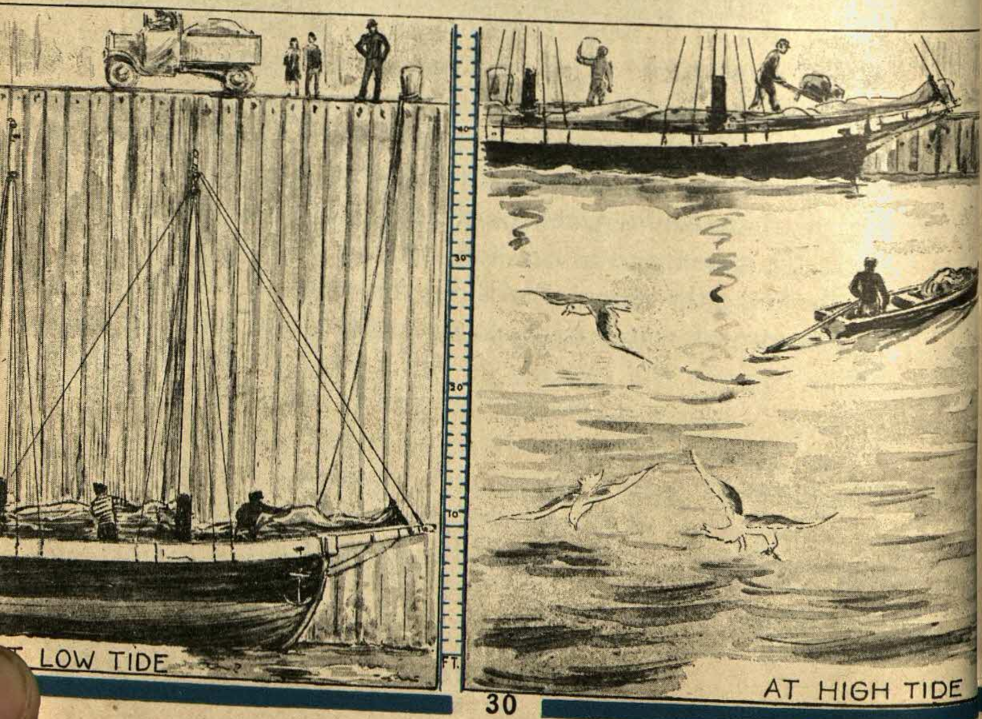
Spring Tides



Neap Tides

line with the moon causes water to be drawn away from other places. Thus, we find two low tides midway between the places of high tide. Since the earth makes one complete spin every 24 hours, the places of high and low tide cannot remain fixed. Every spot on the earth, then, must every day cross a line where the pull of the moon is greatest and another line, on the opposite side of the earth, where it is least. The two high tides lie on these lines. Every place on the seashore has two high tides and two low tides every day.

Since the moon revolves about the earth once in about 29 days, the line of pull changes from day to day. Hence, high tides and low tides do not occur at the same hour every day. Each day brings high tide about three-quarters of an hour later than the day before.

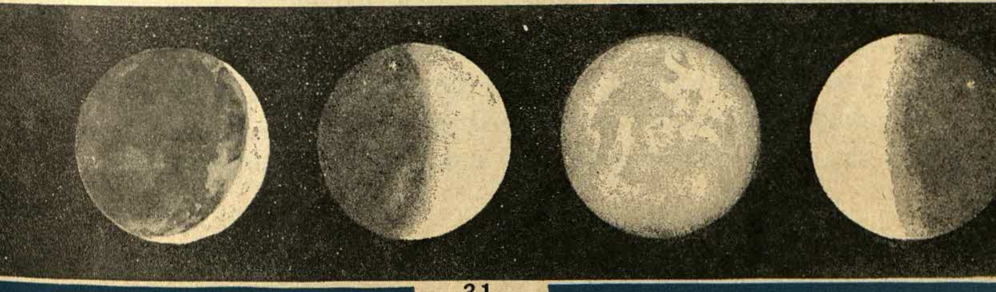


The sun, too, affects the tides; but not as much as the moon, because it is much farther away. Twice a month the sun and the moon pull on the earth's waters together. This produces the highest tides—*spring tides.* When the pull of the sun is at right angles to the pull of the moon, we get the lowest or *neap tides.*

Out in the open ocean the waters do not rise enough to be noticeable. At the seashore the water tends to pile up against the land. In bays which are funnel-shaped, the water may rise many feet as the rising water is squeezed between the shores. In the Bay of Fundy between Maine and Nova Scotia, the water may rise forty or more feet between low and high tides.

Why does the moon look different from day to day?

One side of the moon is always toward the sun and so receives and reflects light. We cannot always see this lighted part because the moon revolves around the earth. When the moon is on the side of the earth away from the sun, we can see the whole lighted portion. This, we call a *full* moon. About a week later the moon has moved to a position where only half of the lighted part shows. This is called the *last quarter.* In about another week, the moon and the sun are on the same side of the earth so that the dark side of the moon is



toward us. This is the *new* moon. At the end of the third week, half of the lighted part of the moon again shows. This is the *first quarter.*

An experiment will show the different appearances, or *phases,* of the moon. Stand in a darkened room. Let one of your classmates carry a globe around you in a circle while another classmate shines a flashlight on it. Draw diagrams of the lighted part of the globe which you can see in various positions. Are they like the shapes which the moon appears to have?

The outline of the whole moon usually can be seen for a few days after the new moon. The side of the moon facing the earth is dimly lighted by sunlight reflected to the moon from the earth. This is *earthshine.*

What is the cause of an eclipse of the moon?

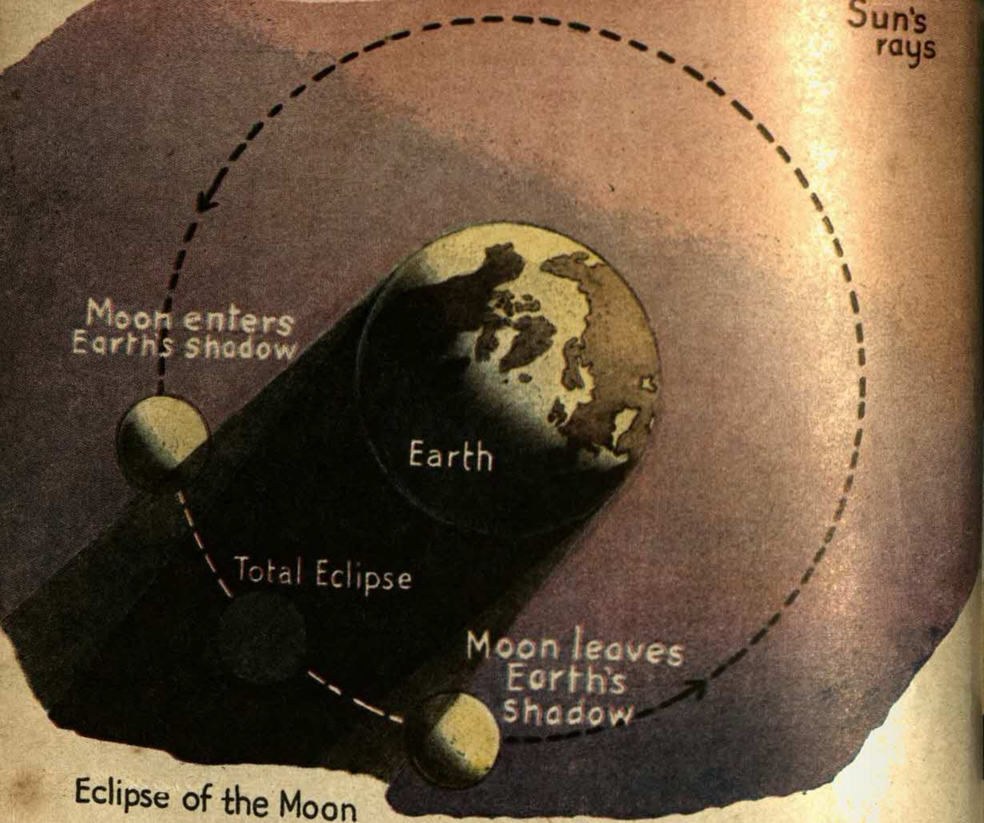
Whenever a bright light shines on an opaque object, there is a space in back of the object which receives no light. This dark space is a shadow. The earth is an opaque object and always has a shadow on the side not facing the sun. Night occurs at places that are in the earth's shadow.

Let us study the shadows cast by a powerful flashlight. Place the light so that its beam strikes a light-colored wall. Now place a ball in the beam. In back of the ball there will be a dark spot or shadow on the wall. You will notice that the shadow is not equally dark in all parts. The center of the shadow is the darkest spot; it receives no light at all from the flashlight. Around the dark center spot is a ring that is partly lighted. The drawing shows the parts of a shadow. The black center

of the shadow is called the *umbra,* and the partly lighted ring is called the *penumbra.*

By casting shadows with narrow beams of light and with broad ones, you will discover that the largest umbra is formed by light which comes from a small source. When light comes from a large source, the umbra is smaller and the penumbra larger.

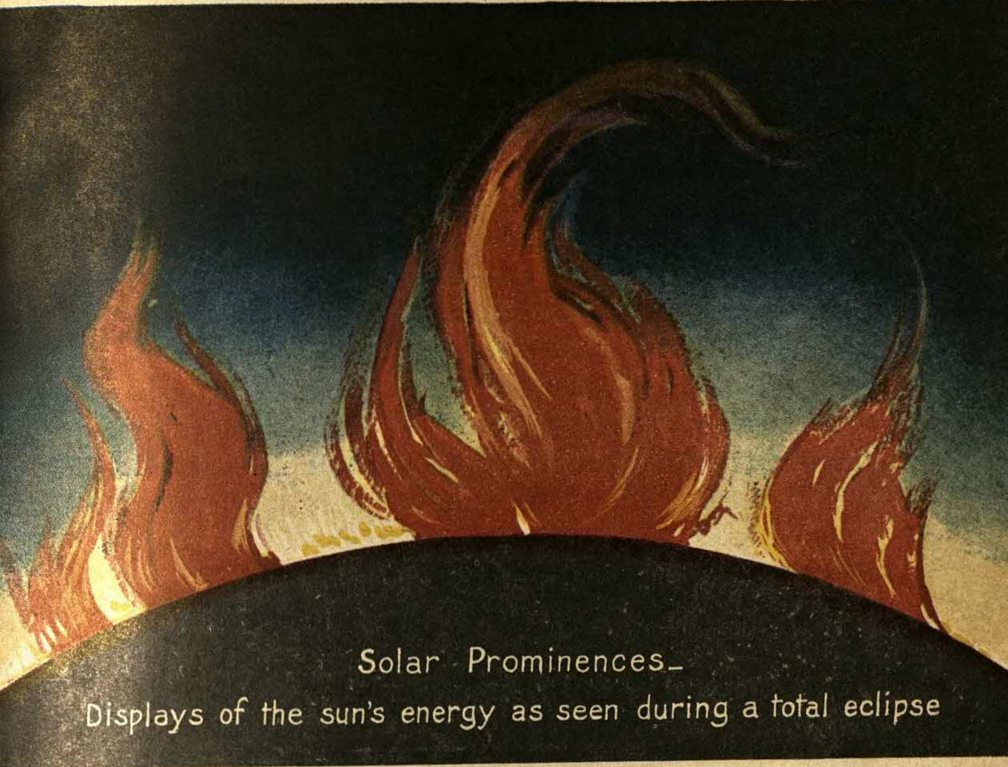
The sun is a very large source of light. It is much bigger than the earth. Consequently the umbra of the earth is cone-shaped, extending out from the earth several hundred thousand miles. Around the umbra is a penumbra which gets larger the farther away it is from the earth.



Eclipse of the Moon

At certain times the moon revolves into a position in which the earth is directly between it and the sun. Then the moon is in the earth's umbra and a total eclipse of the moon occurs. If the moon moves only into the penumbra of the earth, the eclipse is partial.

Eclipses of the moon usually occur twice in a year, although it is possible that there may be none or only one. Rarely, there are more than two. The number of eclipses in a year depends upon the motions of the earth and moon with respect to each other.



Solar Prominences—
Displays of the sun's energy as seen during a total eclipse

Energy from the Sun

Sue burst into the room with bundles in her arms.

"Did I get a surprise today!"

"What has happened now, Sue?"

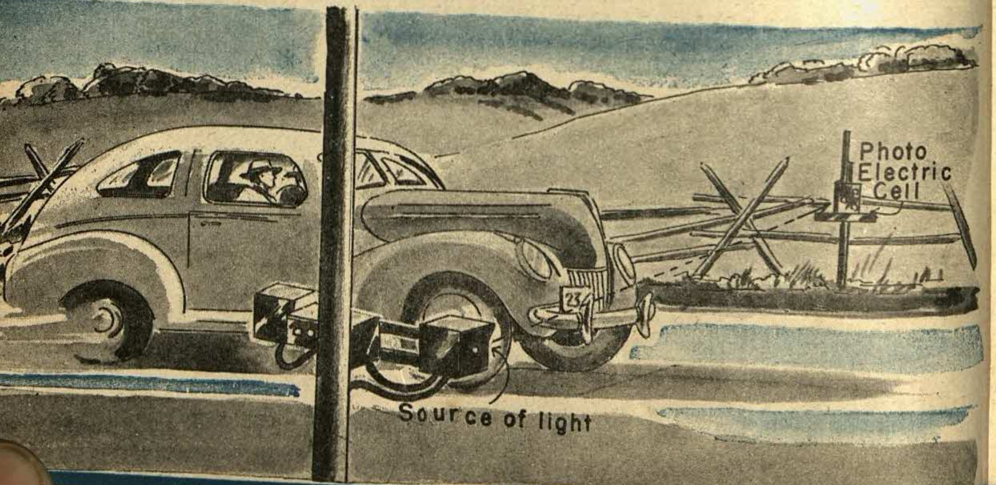
"I was having a soda today. When the busboy took a tray of glasses out, I noticed that the door opened without being touched. It did it every time."

"Oh! I know what did it. Just the other day, our physics teacher was showing us how an electric eye can be used to do such things."

"An electric eye?"

"Yes, scientists call it a photoelectric cell. When light shines on certain things, it makes an electric current. Then the electric current can be used to do all sorts of things."

Photoelectric cells can be made from several different substances. Some kinds use selenium. Others use potassium or caesium. When light strikes these substances, a small electric current is started. This can be made to operate a switch which may start motors, ring bells, open doors, turn on lights and do many other things. The light does not have to be visible. Invisible ultraviolet light is sometimes used in operating burglar alarms. A beam of ultraviolet light is made to shine on a photoelectric cell. If anything crosses the path of the beam, a switch closes so as to sound the alarm. Cars which pass along highways can be counted by placing a source of light on one side of the road and a photoelectric cell on the other. Every car which passes interrupts the beam. A counting device makes a record of the number of interruptions.



Scientists have been interested in the photoelectric cell because it offered a possible means by which the energy of the sun might be used directly for running motors and doing work. At present the energy of sunlight must be stored in plants, in fuel or in water before we can use it. We have no way of using it directly to run machinery. Unfortunately, photoelectric cells cannot make available the large amounts of electricity needed for running powerful motors. Other ways may be found in the future. Possibly, the time may come when we will catch the sunlight which streams down on the roofs of our houses and make it do useful work for us.

What is sunshine?

Before we can truly understand what sunshine is, we must consider the conditions on the sun that produce it. Since the sun is a very hot object, we will find it helpful to study what takes place when any object is heated here on earth.

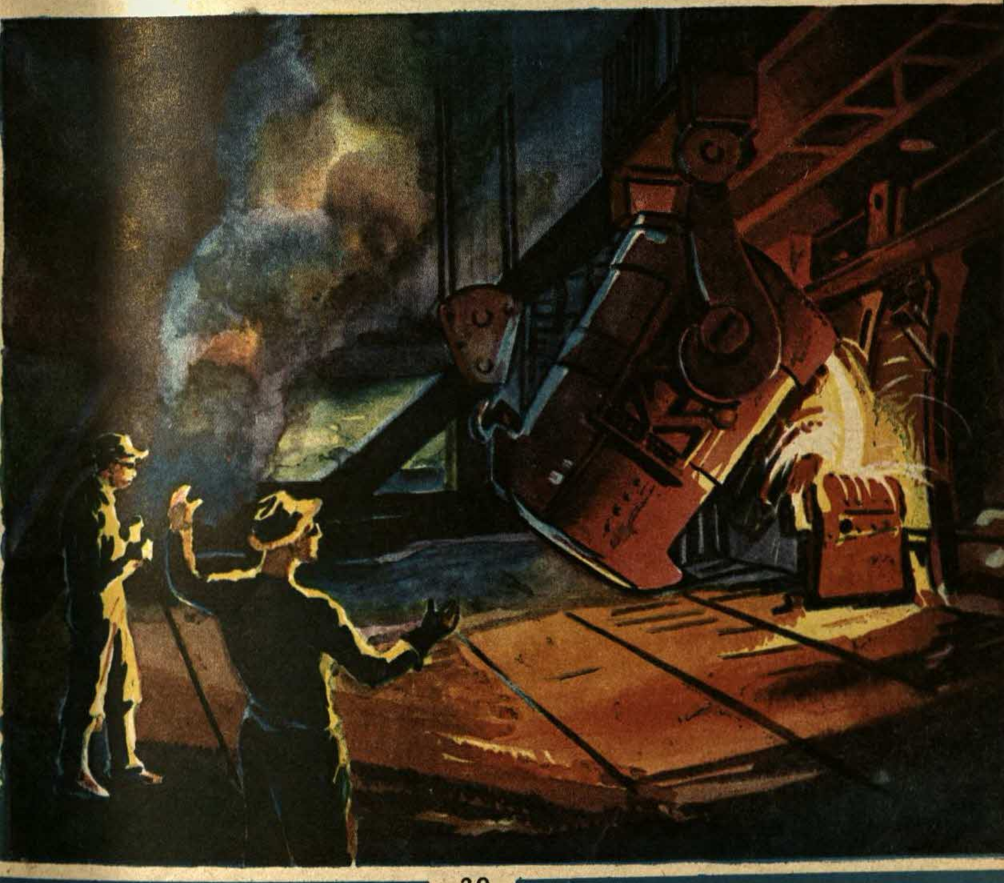
We already know that all substances are made up of tiny particles, sometimes called *molecules.* We know also that the particles are forever moving. As substances are heated the particles move faster. Most solids melt when heated enough, because the increased motion of the particles makes it impossible for them to stay in the places which they occupy in solids. If liquids are heated hot enough, the molecules fly away from each other and a gas is formed.

There are other noticeable things which happen when an object is heated. Heat an iron bar for a minute or two in a bunsen burner flame. Then hold it near your

hand or your cheek. You feel warmth from it. The warmth is not due to air heated by the iron, for you can feel the heat just as well when your hand is held under the iron as when it is held above it. You can feel the heat from the hot wire in an electric light, even though it is completely enclosed in a glass bulb. Something must come from hot objects which can pass through air and glass.

Scientists tell us that an iron bar absorbs heat when it is held in the flame and that the absorbed heat is present in the bar in the form of more rapid motion of its particles. The heat energy of the flame has been changed into energy of moving particles. When the bar is taken from the flames, it cools. The particles lose the energy of motion which they have received. The rapid motions of the particles in a body cause disturbances in the space around them. The disturbances go out in all directions in what are called *radiations*. As the radiations leave the bar, the particles move less rapidly and so the bar gets cooler. These radiations are able to pass through air, glass and other transparent materials. When they strike objects like our hands, the radiations produce the feeling of warmth.

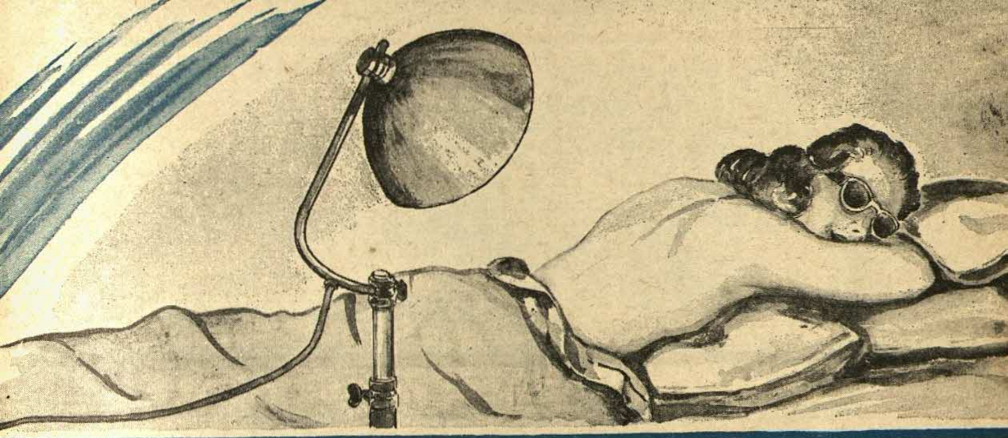
Place the iron bar back into the flame and keep it there for several minutes. After a time we notice that it begins to change color. Instead of the black color which the bar first had, a dull red appears. With con-



tinued heating, the color gets rosy red, then orange, and yellow and finally, white, if the flame is hot enough. When we take the white-hot iron from the flame, the color gradually changes back again to the original black. While these changes are going on, we feel radiated warmth as before. The radiation is even more intense, for we cannot put the hand very near without burning it. But in addition to the radiation that warms the skin there is something else. There is a radiation which affects the eyes. It is with our eyes that we are aware of the color changes. Like the radiations which heat the skin, those which affect the eyes can pass through air and glass and other transparent things. The radiations which affect our eyes are called light.

Some of us may have seen melted iron in the mills where steel is manufactured. In the furnaces, the melted iron glows with a light so strong that the workmen must protect their eyes with dark goggles. Not only does the melted iron give off heat and light but it also gives off radiations which can burn the skin and eyes in much the same way as certain rays from the sun cause a sunburn when we go to the beach on a hot summer day. Radiations that affect us in this way are called ultraviolet rays.

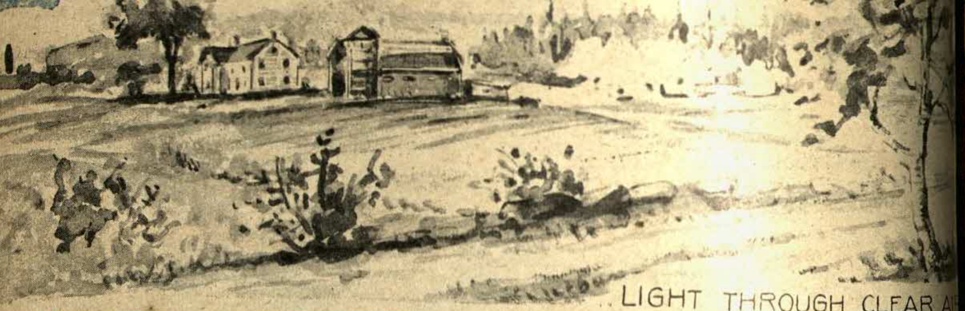
Thus, we see that very hot objects continuously give off a mixture of radiations which go out in all directions, and that these radiations can pass through transparent things. The invisible radiations which warm us when they strike the skin are heat rays or, as the scientists say, infrared rays. The radiations which cause us to see are called light rays, while those which we cannot



see or feel but which cause chemical changes in the skin are called ultraviolet rays. Sometimes ultraviolet rays are used in the treatment of certain diseases. Lamps which produce these rays are often called sun lamps.

The sun is many, many times hotter than anything we have on earth. Scientists tell us that the surface of the sun has a temperature of around 6000° F. and that the inside is much hotter. Even with the hottest flame or the most powerful electric sparks, man cannot produce temperatures much higher than 6000° F. The hottest furnaces which man can make are indeed small and feeble in comparison with the vast size and hotness of the sun.

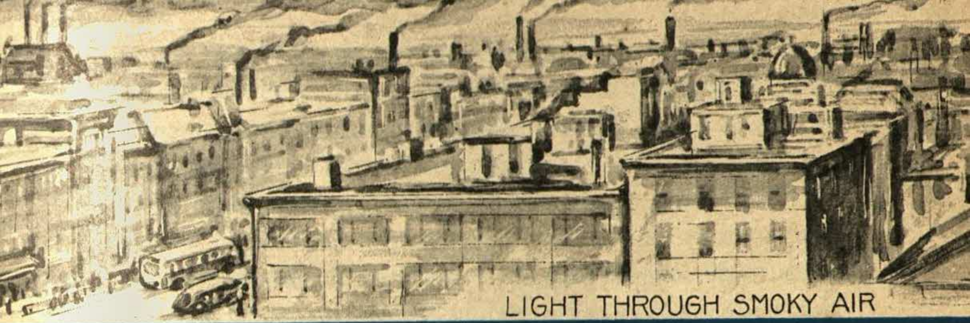
As we should expect, huge amounts of radiations fly out from the sun in all directions. Also, as we should expect, these radiations contain infrared rays, light rays and ultraviolet rays. Possibly there are other radiations, too, because the sun is so hot. The amount of energy which does radiate from the sun is so huge that we can



LIGHT THROUGH CLEAR A

scarcely imagine it. Even the amount which strikes this little earth of ours, 93,000,000 miles from the sun, is so great that we can scarcely believe it. For instance, we are told that one square foot of surface at right angles to the sun's rays receives enough energy every second to lift a person weighing 100 pounds nearly a foot.

Sunshine is the mixture of radiations which come from the sun. The infrared radiations bring warmth to the earth and affect the growth of plants, the evaporation of water, and the winds. Light from the sun makes seeing possible and it furnishes the energy for photosynthesis. We recall that photosynthesis is the process in plants by which all the food of the world is manufactured. The ultraviolet rays have important effects, too. One of the most interesting is the effect on our skins, for it is by the action of ultraviolet rays that we get sunburned and tanned. The ultraviolet rays cause the formation of vitamin D in our bodies and also in certain substances used as foods. It is important to realize that ultraviolet rays are dangerous as well as beneficial. In too great amounts they can do damage, as anyone who has had a severe case of sunburn knows.



LIGHT THROUGH SMOKY AIR

They are destructive to all forms of life, including bacteria. It is the ultraviolet rays which help to destroy bacteria in water. It is fortunate that a large part of the ultraviolet rays never reach the earth. They are stopped by the atmosphere. Smoke and dust over cities may prevent these rays from reaching us even in the small amounts which we need to maintain good health.

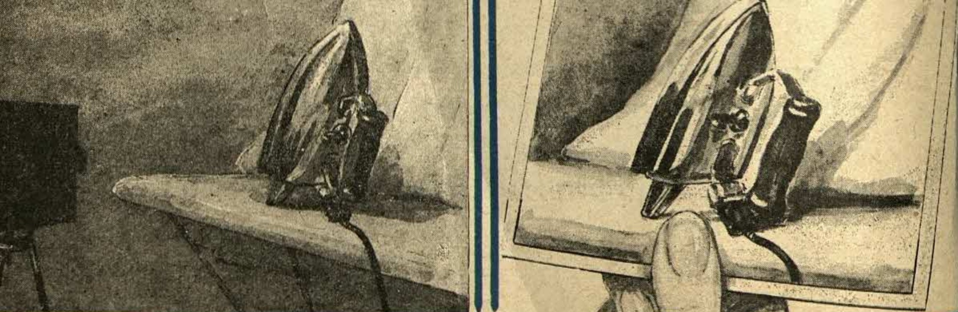
We have suggested that other radiations, in addition to the three just described, may come to the earth from the sun. While we do not yet know the whole story, there is little doubt that the static which often disturbs radio reception is caused by radiations from the sun. Often these disturbing radiations come at times when there are many sunspots. The northern lights are probably also due to radiations from the sun that cause the atmosphere high above the earth to glow with strange moving lights.

How does the energy received from the sun vary?

There are many things which affect the amount of energy that we receive in the radiations of the sun. For a part of each 24 hours, most places receive no sunlight because they are turned away from the sun. As we have already learned, the angle at which the rays strike makes a great difference in the amount of energy received. We get largest amounts of radiations when the sun is directly overhead and less as the sun is nearer the horizon. Each day the energy varies, being small at sunrise, increasing to a maximum about noon and decreasing again as the sun sets. As the seasons change, the angle of the sun varies and the energy received varies, too. In winter in the United States the energy received is very much less than in the summer. This is true because in winter the days are shorter and the sun is nearer the horizon.

The atmosphere greatly affects the radiations which reach the earth. Even the clearest air stops most of the ultraviolet rays. As the amounts of dust, water vapor and clouds in the air increase, both ultraviolet rays and light are reduced. Infrared rays are stopped less by the atmosphere than are the other radiations. Very good pictures can be taken using films which are sensitive to infrared rays, even when the air is so hazy that distant objects cannot be clearly seen. The infrared rays pass unchanged through air which stops much light.

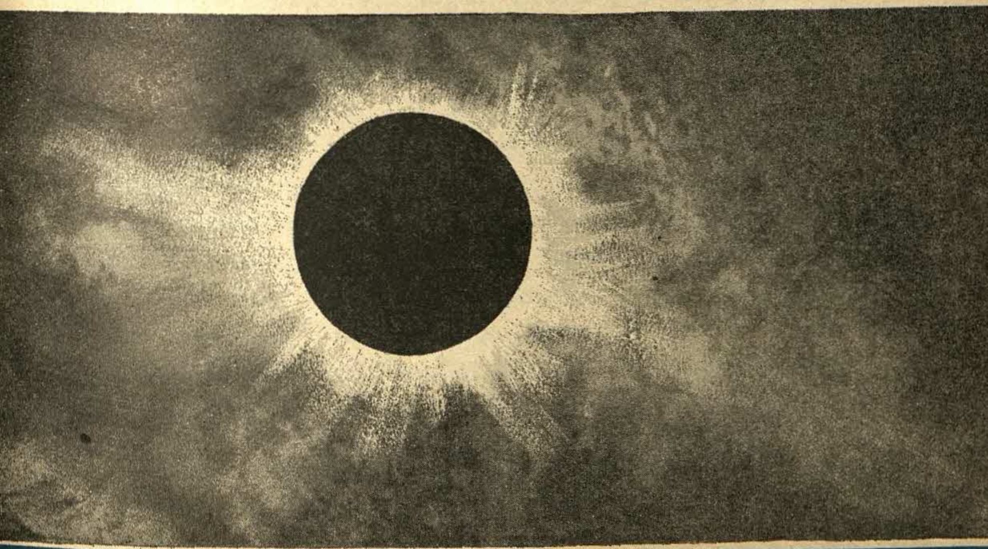
A PHOTOGRAPH MADE BY INFRARED RAYS IN A DARK ROOM



What causes an eclipse of the sun?

A few times in our lives we may have the good fortune to experience the thrilling sight when the radiations from the sun are suddenly cut off for a few minutes by the moon passing between the earth and the sun. Eclipses of the sun are seen less often at any one place than eclipses of the moon, not because they are less frequent but because the moon is smaller and hence only a small part of the earth is ever in the moon's shadow.

The shadow of the moon is exactly like the shadow of the earth except for size. The umbra is cone-shaped and is about 240,000 miles long. We know that the distance from the earth to the moon is also about 240,000 miles. This shows us that the tip of the moon's shadow will only barely reach the earth. Actually, there are times when the shadow cannot reach the earth because of small changes in the distance from the earth to the moon. The moon is never near enough for its umbra to cover an area on the earth more than 160 miles in



diameter. Surrounding the umbra of the moon is a penumbra, which is much larger. See page 33.

There are always at least two days in a year when the moon comes between the earth and the sun. Whenever the tip of the moon's umbra touches the earth, the sun is completely hidden and darkness falls on the area of the earth where the umbra falls. A total eclipse of the sun never lasts more than a few minutes, for the motion of the moon and the earth is so rapid that the shadow sweeps along at a speed of several hundred miles an hour. A total eclipse of the sun is always less than eight minutes in length, as seen at any one place.

As we view a total eclipse, we see the moon move across the sun, gradually covering more and more of it until the sun is no longer visible. After a few minutes an edge of the sun appears again, then more and more of the sun comes into view until finally it is wholly visible again.

On either side of the place where a total eclipse is visible, there is a much larger area which is in the penumbra. Here, the sun is never completely covered by the moon and so only a partial eclipse is seen.

Scientists are much interested in total eclipses of the sun, for it is only at that time that the layers of gas which stream far out from the sun's surface can be seen. Expeditions are often sent to far corners of the earth to observe total eclipses. It is remarkable that the motions of the earth and moon have been studied so well that it is possible to tell exactly to the second when a total eclipse will come and to know with certainty just where the moon's shadow will touch the earth.

Things to Do

1. Make disks of cardboard to show the relation between the sizes of the planets. Represent the earth by a disk one inch in diameter and calculate the sizes of the others from the table on page 11.
2. Obtain two convex lenses from a high school physics teacher or an optician. Hold one lens near your eye and the other at a distance from it. If the lenses are held at a proper distance from each other, objects at a distance appear larger. Lenses used in this way make a simple telescope.
3. Secure a wooden box about eighteen inches square and a foot deep. Mount an electric light socket in the center of the bottom with a cord attached. Make cardboard covers for the box with holes cut to represent the stars in a constellation. Tissue paper should be pasted over the holes. The light shining through the tissue paper gives an excellent illustration of a constellation.
4. If you have a lantern slide projector, you can make interesting slides of the constellations by drawing diagrams of them on pieces of cellophane and mounting them between two pieces of glass.
5. From an almanac, find out when eclipses of the moon will occur. If an eclipse is visible from your city, arrange a meeting of the class to view it.
6. Select a committee of the class to prepare a report about famous meteorites that have fallen to earth.
7. Scientists often make long journeys to view eclipses of the sun. Make a report to your class of an expedition to view an eclipse.
8. The tides have been suggested as means for creating power to run machinery. How is this possible?
9. Attempts have been made to use the energy of sunlight for boiling water and making steam for run-

ning engines. Make a report of how this can be done. Will these devices be widely used? Why?

10. Prepare a report on ultraviolet light and its uses.

How Much Do I Remember?

I. A question is printed below in code. Directions for solving the code are given. *Please do not write in the book.*

Question: Q Z X M Z F S Y G B J H F Z G N F L X B C N?

Directions for solving the code:

Q—Change to A if the moon is larger than the earth. Change to W, if Galileo discovered the moons of Jupiter. Otherwise, change to E.

Z—Change to M if the planets move in orbits which are true circles. If not, change to H.

X—Change to R if Mercury is the largest planet. Change to N if Uranus is the largest planet. Change to I if the sun gives off heat and light.

M—Change to C if moving objects have inertia. Change to Q if the sun is the only body which exerts the force of gravity. Otherwise, change to R.

F—Is the space between words and should be left blank.

S—Change to U if the sun is 93,000,000 miles in diameter. Change to P if the action of inertia and gravity cause the planets to move in curved paths.

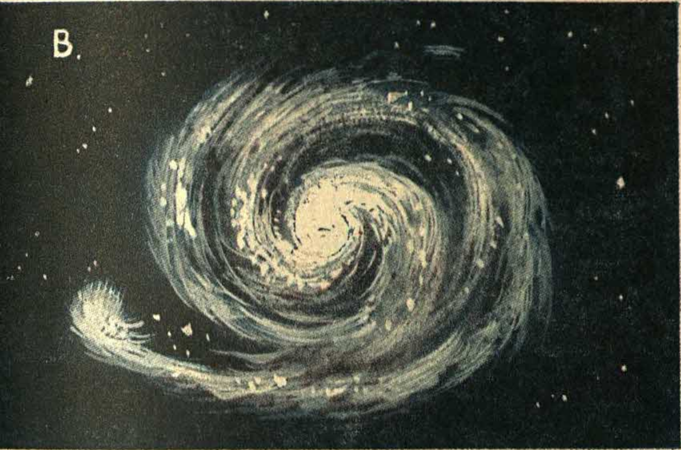
Y—Change to L if aluminum is found in the sun. Change to X if the surface of the sun is smooth.

G—Change to B if sunspots are the shadows cast by mountains on the sun. Change to C if the earth receives one-half of all the energy sent out by the sun. Otherwise, change to A.

B—Change to E if comets are burned up when they enter the earth's atmosphere. Change to O if

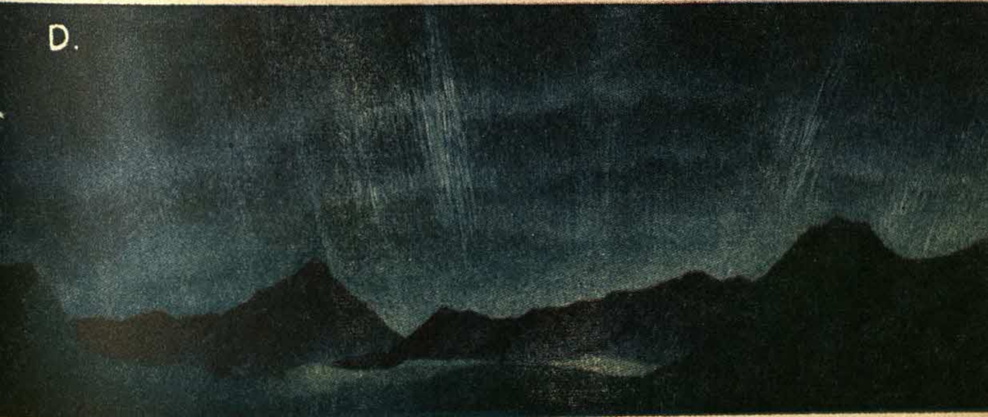
A.

B.



C.

D.



A. Why is the Harvest Moon different from other full moons? When does the Harvest Moon occur?
B. What is the name of this type of heavenly body? What are they?
C. Why will February have 29 days in 1956?
D. From what parts of the earth can this be seen regularly? What is believed to be the cause?

meteors have lighted tails. Otherwise, change to N.

J – Change to E if there are conditions on Mars which may be suitable for life. Change to S if we are certain how the earth was formed.

H – Change to M if there are large lakes on the moon. Change to Y if objects weigh more on the moon than on the earth. Change to T if day and night are caused by the rotation of the earth on its axis.

N – Change to O if daylight lasts for six months south of the Arctic Circle. Change to S if the time used in the United States is mean solar time. Change to T if each month is the exact number of days for one revolution of the moon about the earth.

L – Change to K if a full moon occurs when the moon and the sun are on the same side of the earth. Change to D if an eclipse of the sun is caused by the earth's shadow. Change to R if a photoelectric cell produces electricity when light shines on it.

C – Change to G if the length of daylight affects the amount of energy received from the sun. Change to L if tides always rise and fall the same amount. Otherwise, leave as it is.

II. Pick out the item in column 2 which best matches each word in column 1. *Please do not write in the book.*

Column 1

A. Jupiter
B. kind of nebula
C. umbra
D. Chamberlin
E. Big Dipper
F. Newton
G. galaxy
H. orbit

Column 2

1. hypothesis about formation of solar system
2. darkest part of a shadow
3. well-known constellation
4. largest planet
5. shining, cloudlike bodies
6. studied force of gravity
7. path of a planet or satellite
8. huge groups of stars

THE SURFACE OF THE EARTH

The Changing Face of the Earth

In the Pacific Ocean there are many volcanoes. Their tops form islands. The rich volcanic soil grows fruits and vegetables abundantly. People do not find it difficult to live on these islands, for the abundant plant life makes food easy to get and the warm climate makes heavy clothing and well-built houses unnecessary. In August 1883, the peaceful island of Krakatoa lay in the Sunda Strait between Java and Sumatra. The native people were going about their daily tasks, giving little thought to the mountain which towered above their island home. Almost without warning, there came a terrific explosion, probably the most·gigantic ever seen by man. In an instant, the mountain disappeared in

a mighty cloud of dust. Huge masses of lava were thrown in every direction.

The force of the explosion sent out a giant water wave 100 feet high. It swept along the shores of near-by islands, completely destroying more than two hundred villages. Thousands of people were killed either by the explosion or the wave. The force of the explosion shot a towering cloud of dust 20 miles into the air. Thousands of tons of rock and earth were broken into pieces so fine that they were carried clear around the earth by the winds. All over the earth there were unusually beautiful sunsets because of the dust thrown up by this volcanic explosion.

So great was the mass of dust thrown into the air that temperatures all over the world were lowered a little, because the sun's radiations could not reach the earth in the usual amounts.

The noise of the explosion was so loud that it was heard in Japan, about three thousand miles away. A portion of the original island disappeared entirely, but new islands were formed by the lava and ashes.

How does heat change the earth's surface?

When the earth was formed, the land surface was made entirely of rocks. Where the earth is not covered

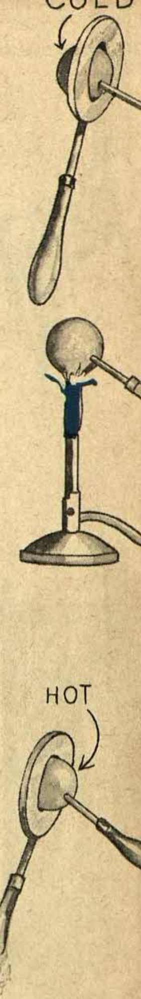
with soil or other loose material, that is true today. Actually the soil contains the fragments left after rocks have been crushed and ground into fine particles.

There are many kinds of rocks. They differ in color, in weight, in hardness and in other ways. But, in one way, most rocks are alike. Most of them are brittle. This means that rocks break or crumble when anything or anyone tries to change their shape. In this respect, a rock acts much like a piece of cold glass. Neither can be hammered or bent or stretched without breaking.

When most objects are heated they expand. There is a very interesting experiment to show this. A metal ball is made which will barely pass through a metal ring when both are at the same temperature. When the ball is heated, it will not slip through the ring. When the ring is heated, it slips over the ball very easily.

When a rock is heated it expands, but the increase in size is greatest on the outside where the heat is applied. The outside of the rock gets a little too large for the inside. This small change in size caused by the expansion is often too great for the brittle rock to withstand, and so it cracks. If you have built a campfire on a bed of stones, you may have heard the sharp reports when the heated rocks cracked. When you put out a campfire with a bucket of water, the hot stones are suddenly cooled. The outside contracts more quickly than the inside, so that pieces crack off.

In high mountains, the rocks are heated strongly by the sun's rays, much more strongly than they are at sea level, for the thin air on mountaintops does not absorb heat rays very much. After the sun sets, the rocks cool



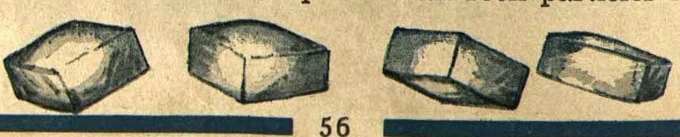
quickly, for heat radiates rapidly at high altitudes. Then, too, sudden showers and snow flurries may cool hot rocks. While the amount of heating and cooling is not so great as in the case of a campfire, still, over a long time, the outer layers of rock become cracked. As these fall away, more rock is exposed and the cracking process continues.

How do water and air change the earth's surface?

Water helps to change the earth's surface in a number of ways. When water freezes, it expands. Ice cubes have humps in their centers where the water increased in size as it froze. On a winter morning, we may discover the milk bottle cap resting on a little column of solid milk which was formed as the milk expanded while freezing. Water expands with great force when it freezes. That is why water pipes may burst in very cold weather.

Liquid water seeps into the cracks of rocks no matter how tiny they are. When the water freezes it widens the crack. Each time water freezes in the same crack, it widens it a bit more. Finally, the rock is split. Over and over again, this process is repeated in all parts of the earth where the weather gets cold enough for water to freeze.

The breaking of rock by changes in temperature and by ice does not cause great changes in the appearance of the landscape until the fragments are carried away. Rocks fall by gravity from steep slopes, piling up in heaps at the bottom. As water falls on hills, it rolls small rocks down the slopes. Small rock particles are



caught up and carried along by running water. In this way water digs a channel for itself. If there is much water, even stones of large size may be rolled and tumbled down slopes and along the beds of streams, digging the river channel deeper. While this is going on, the stones are jostled together and are chipped and broken still more. The smallest and lightest particles are carried farthest down the valleys. As the water in streams and rivers approaches sea level and thus flows more slowly, it cannot carry loads of sand and other rock particles, so these are deposited along the banks and at the bottom of the rivers.

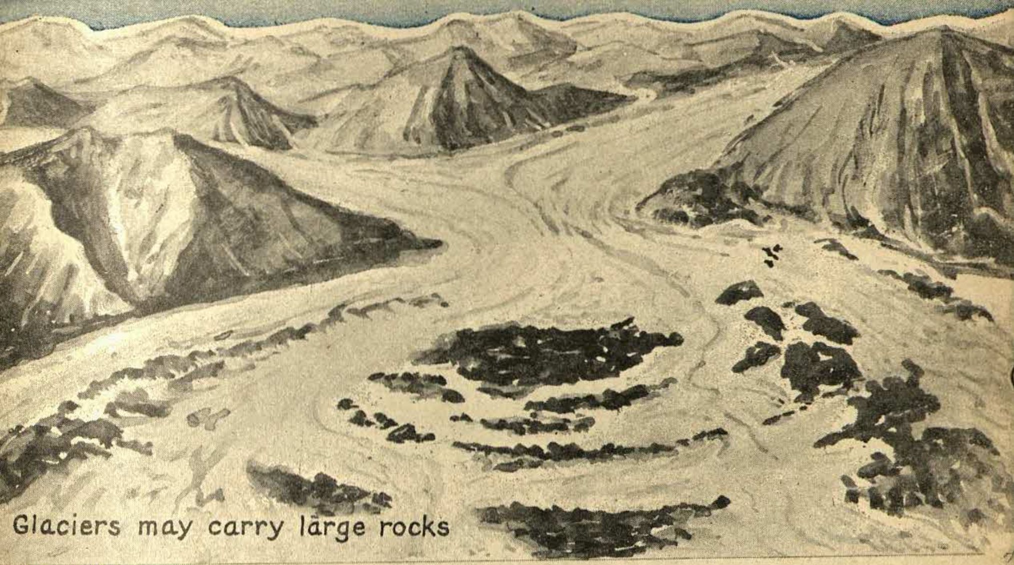
Running water is forever carrying materials from the high parts of the land to the lower places. That is one reason for finding mostly barren rocks on mountaintops, while the valleys have soil which has been brought down from higher places. Year by year the highest parts of the land are being lowered and the lowest parts are

being built higher. But, so slow is this process that many years, often centuries, pass without any noticeable change in the height of mountains.

Now and then we do have a chance to see what a powerful mover water is. During floods, river banks may be gouged away, new channels may be formed, bridges, buildings and roads may be undermined and swept away. It is then that we can understand the mighty force of moving water.

Moving water helps to change the surface of the earth in another way. In the higher mountains which are snow-capped the year around, great drifts form in the

THE GRAND CANYON – formed by moving wate



Glaciers may carry large rocks

steep valleys between peaks. As the snow gets deeper, the weight presses the snow into ice. The ice mass begins to move very slowly downward. Such a moving mass of ice is a glacier. Even though glaciers may move only a few inches or a few feet daily, they can do tremendous work. Rocks which are frozen into the sides and bottom of the ice mass act like plows in tearing the underlying rocks. At the ends of glaciers where they melt away in the warmer valleys, great heaps of stones of all sizes are left. All these have been carried from higher places by the moving ice.

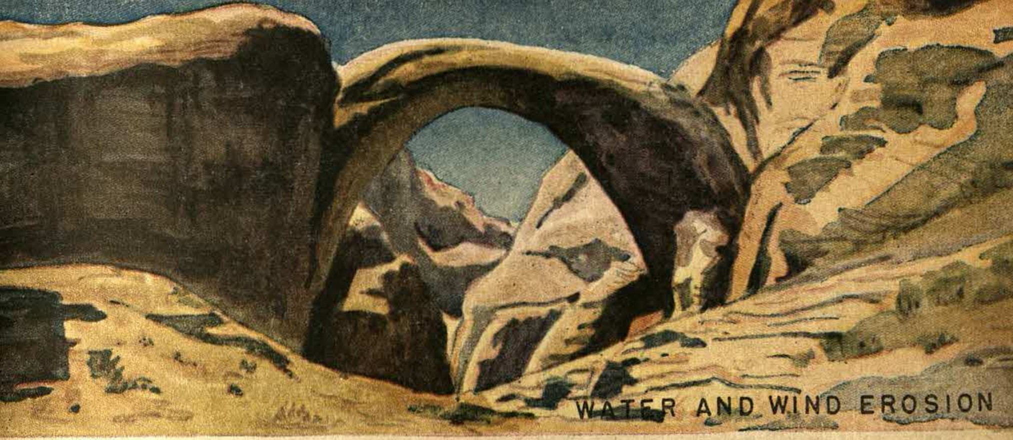
Sometimes glaciers form over great areas. Such glaciers exist today in Greenland and on the Antarctic continent. As these great ice sheets move, they scour off the hilltops and fill in the valleys. Many thousands of years ago such an ice sheet covered much of Canada and the northern part of the United States. To this day,

scratches made in rocks by this great glacier are visible. Great heaps of gravel were left by the glacier in many places when it finally melted away.

Water helps to wear down the land in still another way. As it trickles through the cracks in rocks and chinks in soil, it dissolves minerals and carries them toward the oceans. In some places, there is limestone, which is slightly soluble in water. By dissolving the limestone over thousands of years, seeping water may form great caves underground. Later the roofs of the caves may fall in, forming pits called *sinkholes*.

Even after water reaches the oceans it can still do work. Ocean waves smash against the land continuously. Slowly the sea wears away the shore, grinding up the rocks into sand and clay. During a storm, the waves beat violently against the shore, breaking away large masses of rock.

The wearing away of the land by water is called *erosion*. Air, also, can cause erosion. Winds pick up small



particles, carry them along and drop them when the speed of the wind is lessened. In the dry desert regions much material is moved by the wind. Sand dunes are mounds of sand which are slowly moved along by the wind. Dust and sand grains, driven by strong winds, wear away the rocks. Sometimes, curious shapes are carved in the rocks by wind-blown sand. Farm land is often destroyed when the wind removes the topsoil.

Air is so light in weight as compared with water that it is far less powerful in changing the landscape. Yet there are times when its work is also very great. In the 1930's there were several years of drought in some of our Great Plains states. As the soil became dry and powdery, the winds swept up thousands of tons of it, causing dust storms. In many cases the dust was carried hundreds of miles.

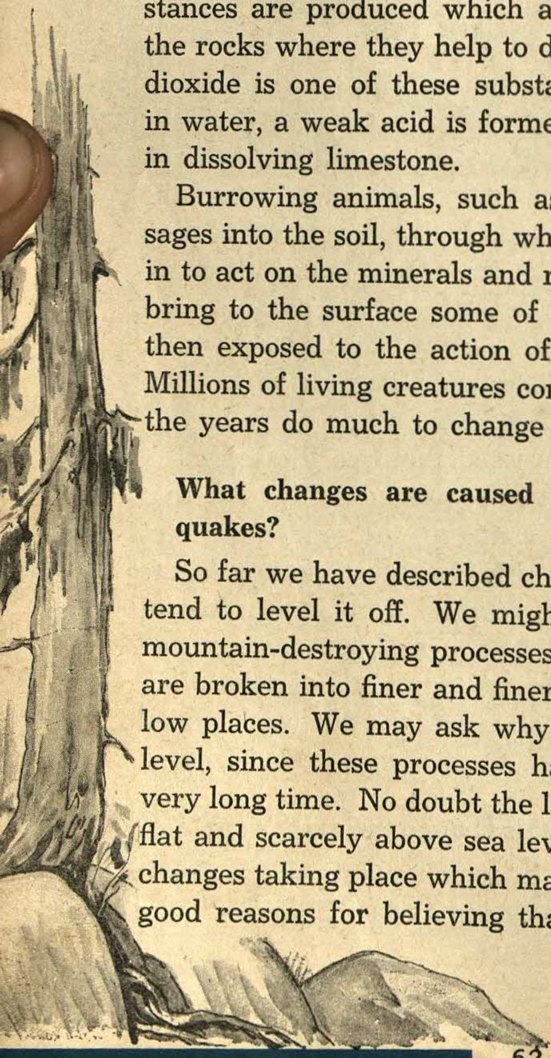
How do plants and animals change the earth's surface?

There are many ways in which plants and animals help in breaking up and wearing away the land. Plants send their roots into the soil in search of food materials. Often they grow into crevices in the rocks, thus prying them open. Many of us have seen blocks of sidewalk tipped and broken by the roots of trees which grew under them. This gives a good idea of the force exerted by growing roots. When plants decay, chemical substances are produced which are carried by water into the rocks where they help to dissolve minerals. Carbon dioxide is one of these substances. When it dissolves in water, a weak acid is formed which is very effective in dissolving limestone.

Burrowing animals, such as earthworms, open passages into the soil, through which water and air can get in to act on the minerals and rocks. These animals also bring to the surface some of the buried soil, which is then exposed to the action of sunlight, water and air. Millions of living creatures constantly working through the years do much to change the land.

What changes are caused by volcanoes and earthquakes?

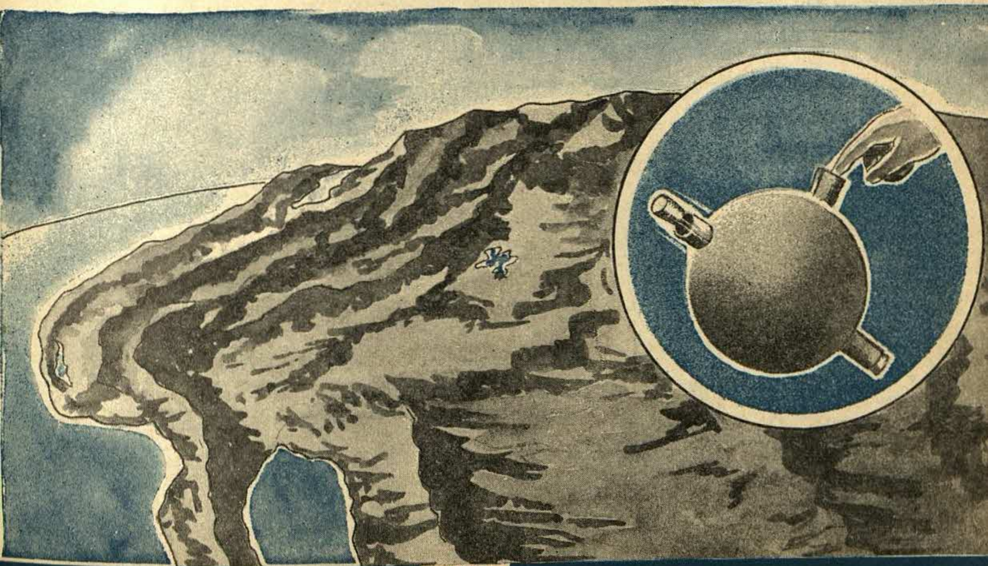
So far we have described changes on the earth which tend to level it off. We might call these changes the mountain-destroying processes, for in all of them rocks are broken into finer and finer pieces and moved to the low places. We may ask why the earth is not entirely level, since these processes have been going on for a very long time. No doubt the land would be very nearly flat and scarcely above sea level now if there were not changes taking place which make mountains. There are good reasons for believing that the present mountains



were formed by the raising of land which used to be much lower. For example, shells of sea creatures are often found in the rocks of mountain peaks. This indicates that the rocks were once at the bottom of the sea. Sometimes sea beaches are found high up on mountainsides, far above the level of the oceans that now exist. Some great force must have pushed the ocean bottom upward, thus forming the mountains.

Scientists have an interesting idea about one way in which mountains may be formed. Let us do an imaginary experiment in order to understand this idea. Suppose we have an iron ball filled with water. At several points on the ball there are openings, each one closed with a tight-fitting stopper. Now, suppose we push one stopper in. The water inside cannot be compressed, so if one stopper is pushed in, some other one must pop out.

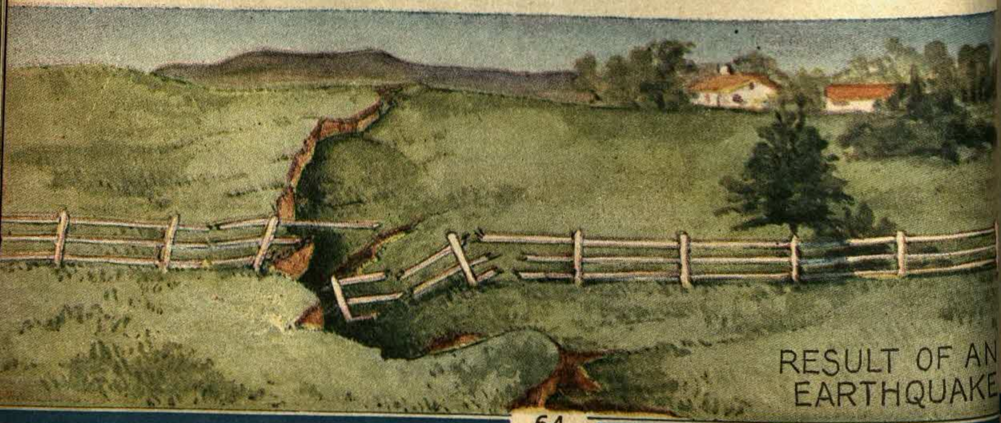
Scientists believe the earth is somewhat like the iron ball filled with water. Of course, the earth is not hollow



nor is it filled with water, but in the interior the materials can flow somewhat like water. It has been learned that most rocks at the bottom of the oceans are heavier than most rocks which make up the land. As erosion goes on, more and more material is carried into the oceans, increasing the load of the rock on the bottom still more. Finally the ocean bottom sinks a little. This represents pushing in the stopper in our imaginary experiment. As the ocean bottom sinks in one place, another part of the earth's surface is pushed upward, just as the stopper moved out in the experiment.

Some mountains seem to have been formed by sidewise movements of the crust of the earth. Lay a newspaper on a table. Press your hands firmly against the paper and then slide them toward each other. Notice how the paper wrinkles up. Long mountain chains may have been formed by similar motions of the earth's crust. We do not know exactly what forces may have caused such motion. Since rocks are brittle, they tend to crack as they are folded up, so that one portion may slide over another to form steep cliffs and jagged peaks.

No doubt many other forces have been at work to form



RESULT OF AN
EARTHQUAKE

the mountain scenery that is so varied and beautiful.

A sudden movement of the earth's surface is an earthquake. Usually earthquakes happen suddenly and with little warning. The forces that cause them gradually become greater and greater until the rocks give way under the strain, just as a stretched rubber band may suddenly break. Nothing, except modern atomic warfare, is more destructive to human life and property than earthquakes in large cities. Not only are buildings shaken down, but gas mains and electric wires are broken, thus starting fires that add to the damage.

A number of very destructive earthquakes have happened in recent times. In 1923 the city of Tokyo was almost wholly destroyed. Over 70,000 persons were killed at Messina in Italy in 1908. In our own country a number of earthquakes have caused great damage and loss of life. Several of them have occurred in California.

It is seldom that any part of the earth moves very far during an earthquake. In the California earthquake of 1906, the greatest movement was 21 feet. Mountains are not made overnight. They are usually made by a great many small movements occurring at intervals over many thousands of years. In 1943, however, there was a volcanic eruption in Mexico that built up a small mountain within a few months.

Earthquakes happen far more often in certain places than in others. All around the shores of the Pacific Ocean, earthquakes occur quite frequently. Another zone in which earthquakes are common stretches through the Mediterranean Sea and across Turkey, Iran and India.

The rocks down in the earth are greatly heated by the forces that cause changes in the earth's surface. In some places the heat due to these and possibly to other forces of which we know very little, causes some of the rocks to melt. A volcano is a place where the melted rock flows to the surface. Such melted rock is called *lava.* Volcanoes are found in many of the places where earthquakes happen. Volcanoes are not always active. Some of them remain quiet for many years and then suddenly erupt again. This was the case with Krakatoa as described in the first pages of this chapter.

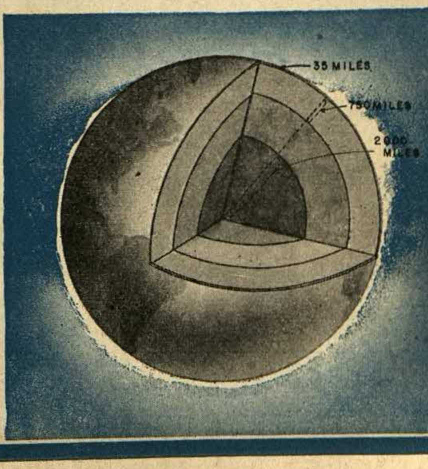
When volcanoes are active, lava flows up from the interior of the earth like water from a spring. Usually gases bubble out of the lava with great force, throwing ashes high into the air. Clouds of steam may rise thousands of feet. The hot lava sometimes streams down the mountainsides, setting fire to forests and everything

burnable. The eruption of a volcano near a city may cause great loss of life and destruction of property.

What do we know about the interior of the earth?

No one has ever been very far into the earth, for the deepest mines go down only a mile or two. Oil wells have been drilled three miles or so into the crust of the earth and samples of rock taken out, but we have had no actual experience with the deep inside of the earth. However, some very interesting descriptions about the earth's interior have been given by scientists. Much of the information upon which these descriptions are based has been learned from a study of earthquakes.

During an earthquake, the earth seems to shiver. These shivers, or vibrations, travel through the earth. Through a study of these vibrations, scientists believe that the earth is made of layers something like a baseball. In the center there is a core, probably made mostly of nickel and iron. This core is believed to be about 2000 miles in radius. The familiar outer crust of brittle granitic rock is about 35 miles thick. The next 750 miles consists of dark-colored, heavier rock. Below this is more of the heavier rock, with increasing amounts of iron as the inner core is approached.



We must remember that this idea of the inside of the earth is only a theory, which must be changed if new facts are discovered that cannot be explained by our present ideas.

Changes in the Rocks

A troop of Boy Scouts, with their Scoutmaster, were taking a nature hike along the shore of a lake. Trees, shrubs, flowers, insects and birds were being observed and identified. The scattered stones of many colors and sizes were being examined. Many of them had been smoothed and worn into curious shapes by the waves.

"Look at this one, Mr. Smith. How could it be so shaped by the water?"

"What have you found, Bob?"

Bob handed Mr. Smith a smooth black stone, somewhat wedge-shaped and with a groove around it not far from the blunt end.

"Why, Bob, you have made a real find. You're right; that stone was not made by the water. It was made by the Indians."

"By the Indians? What is it? What did they use it for? Let me see it!" The boys gathered around.

Stone Implements

Cave man

"Let's sit down under that tree and I'll tell you something about it.

"Human beings are different from other animals because they have a better brain and so can plan to do things better. Also, we have hands which are much better for holding objects than are the feet of animals. Thousands of years ago, man began to use various things to help him get food and to do his work. He cracked nuts with sticks or between stones instead of with his teeth. He threw stones to protect himself from animals. He probably killed animals that way, too.

"In doing these things, men were using what we now call tools. Today we make tools from metal, but thousands of years ago metals were not common. Then, stone was about the best material for making tools because it was hard. Some stones could be chipped and polished against other stones to make sharp edges. Knives, axes, drills and arrowheads could be made in this way. This stone of Bob's is an axe. You can see how a stick could be bound with leather strings into this groove to make a handle.

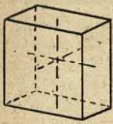
"All over the world, primitive people used stone tools. We must go to the museum one of these days to study the collections there. As a matter of fact, much of what we know about early people has been learned by studying the kinds of tools they made."

"Mr. Smith, do these stone tools have anything to do with the Stone Age?"

"Yes, Harry. The period during which people made most of their tools from stone is called the Stone Age. In Europe, people learned to use metals over two thou-

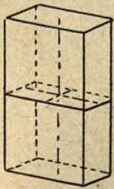
Pre-Indian

Indian Arrow-heads



sand years ago and gave up the use of stone for tools, but the North American Indians were still living in a Stone Age when the white men first came here."

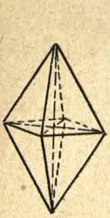
What are the main kinds of rocks?



Let us ramble along the shore of the ocean or a lake and examine the rocks. They are not all the same. Some are light in color, others dark. Stones of the same size do not always have the same weight. Some rocks seem to be made of grains which are all alike, while others are mixtures of as many things as a fruitcake. In museums, we find collections of rocks with hundreds of different specimens, all differing from each other in some way.

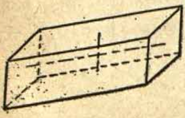
In spite of the many differences, there are only three main kinds of rocks—*igneous, sedimentary* and *metamórphic*. The names indicate the processes by which they were formed.

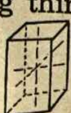
The first rocks formed in the earth were igneous rocks. Whatever may have been the method by which it was formed, the earth was very hot—so hot that the materials composing rocks were melted. When the melted material cooled, it formed the igneous rocks.



The material of igneous rocks is not a single substance but a mixture of various things. If we were to examine the melted substances—lava as an example—we should not be able to see separate things. However, when the mass of melted substances cools, the different things in the mixture separate and form little angular lumps which we call *crystals*.

Crystals are fascinating things. The crystals of any

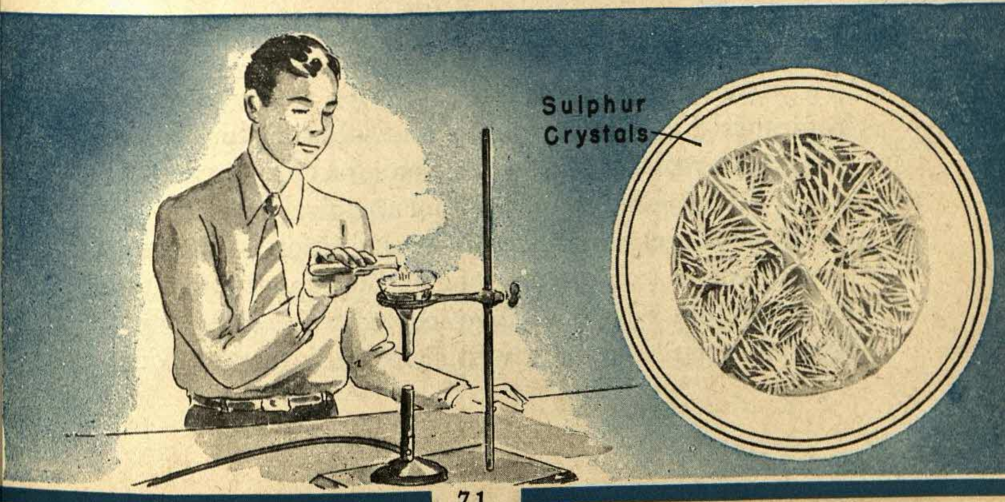




Different shapes of crystals

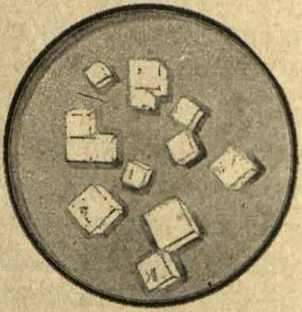
substance have the same shape, but different substances have crystals of different shapes. Crystals always have flat surfaces and straight edges, when formed where they are not crowded together. In rocks, the crystals are usually packed tightly together with the result that the crystals are not perfectly shaped. We can usually tell whether crystals are present in a rock by a simple test. Hold the piece of rock in sunlight and turn it from side to side. If it has crystals, their flat surfaces will act like little mirrors, causing the rock to sparkle with pin points of light.

There are many methods by which crystals can be made. But it is not easy to make them in the same way that they are formed in rocks, for most materials do not melt easily. However, sulphur melts easily enough so that crystals can be made from it. Fill a test tube two-thirds full of sulphur and melt it over a bunsen flame. Take care to heat the sulphur barely enough to melt it. It will form a clear yellowish liquid. Pour the melted sulphur into a cone of paper held in a funnel. As the

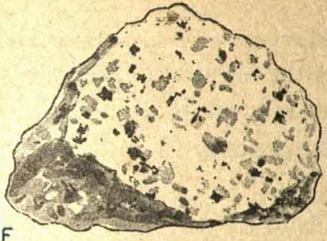


sulphur cools, you will see thin projections grow out from the edges of the pool of liquid. When the surface is nearly covered, open the cone and pour out the remaining melted sulphur. You will find the paper has a layer of thin, needle-like crystals of sulphur.

Crystals are more easily formed from solutions than from melted substances. Dissolve some common salt in water and let the water evaporate slowly. When the water has disappeared, you will find small cubes of salt left. You can see through a hand lens that they are entirely different in shape from the sulphur crystals. No matter what we may do, salt crystals always form in exactly this cubical shape. Likewise, crystals formed from melted sulphur are always needle-shaped.

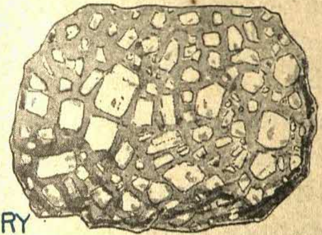

SALT CRYSTALS

Igneous rocks, with few exceptions, are crystalline rocks, differing from one another mainly in size and in the kinds of crystals of which they are made. The size of crystals seems to be determined by the time that it takes for the liquid rock to become cooled to a solid. When lava pours out of a volcano it cools very quickly, form-



GRANITE

OBSIDIAN



PORPHYRY

PUMICE (FLOATING)

ing very tiny crystals which usually cannot be seen without a magnifying glass. One kind of igneous rock actually has no crystals. This is obsidian, which is really a kind of glass.

Sometimes lava is mixed with bubbles of gas. When such lava cools, the bubbles remain scattered among the solid materials. This stone is pumice, which is often very light because it contains gas bubbles. Hence, pumice will sometimes float on water.

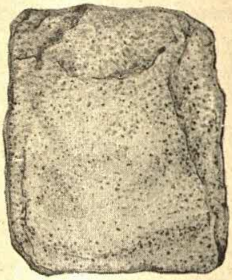
Much melted rock never comes to the top of the ground. It cools slowly in the earth. Hence, larger crystals are formed which can be seen with the naked eye. Granite is a very common rock of this kind. Granite may be of various colors due to the presence of small amounts of colored substances.

Porphyry is one of the most interesting igneous rocks. It is made of large crystals scattered through a mass of fine crystals. It is believed that the liquid rock cooled slowly at first, thus forming large crystals. Then for some reason, the remainder cooled quickly, forming the small crystals.

We have already studied the action of water in carrying the material formed from broken rock to other places. Water can carry particles of broken rock only when it is moving. The more rapid the motion of the water, the larger the particles it can carry. Finally, running water reaches a lake or the ocean and ceases to flow. Then the particles of broken rock which it carries fall to the bottom as sediments. If these sediments become stuck together, a sedimentary rock is formed.

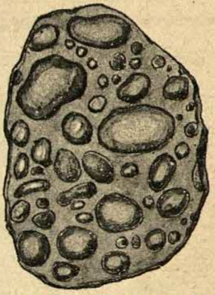
Sedimentary rocks often consist of layers because the particles of which they are formed are deposited at the bottoms of bodies of water, a little at a time, one layer on top of another. As the sediments become thicker, the lower layers are squeezed together tightly by the weight of the upper layers. Often water soaks through them, leaving minerals which act like glue to cement the particles together. Thus a rock is formed.

Clay consists of very fine particles which are deposited



SANDSTONE

SHALE



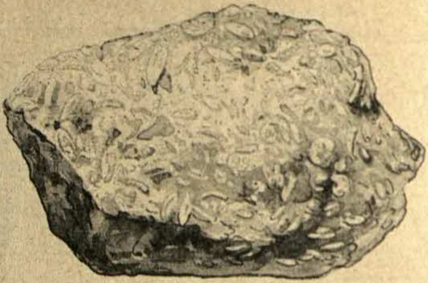
PUDDING STONE

only when water is very quiet, as is the case in large lakes or in the ocean. When deposits of clay become compressed and cemented into rock, shale is formed. Shale often consists of thin layers which can be split apart.

Sand consists of coarser particles than clay. Slow-flowing water cannot carry sand particles, so it is often found in the beds and along the banks of rivers as well as along the seashore. When sand is cemented together, *sandstone* is formed.

Conglomerate, or pudding stone, is an interesting kind of sedimentary rock. It is made of gravel, which is a mixture of stones of many sizes. Gravel may be formed in a number of different ways. Glaciers may carry along fragments of rocks of different sizes. These are left as the glacier melts away. Rapid-flowing streams, especially in mountainous regions, may roll and tumble stones along their beds to form deposits of gravel. Other deposits are formed where ocean waves beat against rocky cliffs, eventually breaking them into fragments.

Some sedimentary rocks are made from materials that have been dissolved in water. Certain substances are



COQUINA LIMESTONE

removed from sea water by different creatures. These animals use the substances to make their shells. When the animals die, the shells fall to the ocean bottom, gradually building up layers which later may be compressed into stone. Much limestone is formed in this way. In some limestone, such as the coquina rock of Florida, the pieces of shells are still plainly visible. In other limestone, the remains of animals have been greatly changed by the rock-forming process.

The third great class of rocks is the metamorphic rocks. They are made from igneous rocks and from sedimentary rocks which have become changed. Heat

MARBLE

SLATE

GNEISS

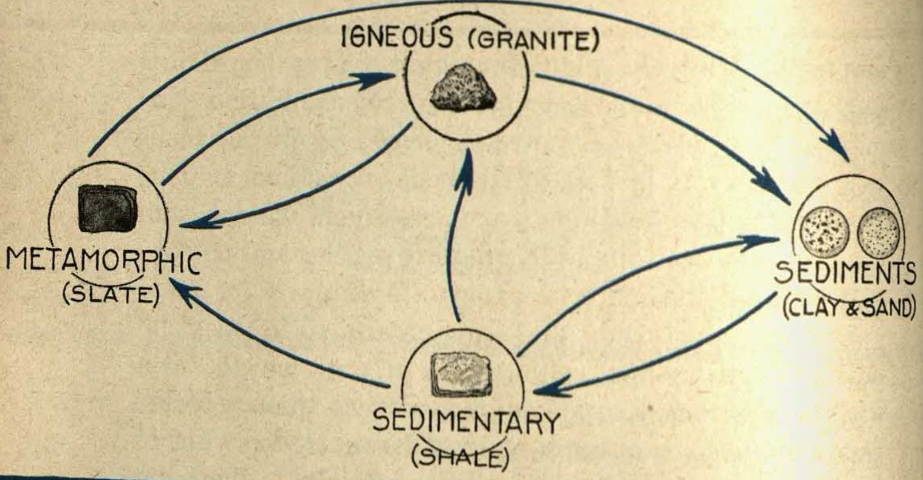
and pressure are the main causes that change the original rocks into their metamorphic forms. Rocks buried deep in the earth must bear up the weight of all the rocks above them. It is believed that the pressure may be several thousand pounds per square inch. Under such pressure the crystals or particles in rocks are crushed and broken.

We know, too, that the temperature within the earth gets higher the farther down we go. As we go down a mine, the temperature increases more than a degree Fahrenheit for every 100 feet of depth. It is so hot in the deepest mines that miners can work only short periods. The high temperature inside the earth may greatly change the substances found in rocks. The conditions which affect rocks are so many and so complicated that we cannot explain all of them here, but we can mention a few of the metamorphic rocks that are formed.

Shale may become changed into the metamorphic rock slate. This material is familiar to us in blackboards and in shingles for buildings. It has these uses because it is fairly hard and can be split easily into thin layers.

Marble is a metamorphic rock formed from limestone. There is no rock which has greater beauty. Marble is found in almost every color and in a great many patterns in which the colors are mingled together to give an interesting appearance.

When granite is subjected to great heat and pressure, it becomes changed into a metamorphic rock showing distinct bands or stripes. Such rock is called gneiss. Unlike slate, most kinds of gneiss cannot be split readily.



What is meant by the rock cycle?

Rocks are forever undergoing changes. The solid rocks are gradually crumbled away into smaller pieces, which are moved to new regions. There the transported material may be made into a new rock. Later on, this may again be broken into small fragments and the process started over again. The constant destruction of old rocks and the formation of new ones remind us of the constant evaporation and condensation of water, which we call the water cycle. Thus, we call the changes that rocks undergo, the *rock cycle*.

Slowly but surely, even the hardest rocks are cracked, dissolved or ground into smaller and smaller pieces. By the action of gravity, running water and winds, the fragments of rock are carried to lower levels and for the most part are sorted out into particles of uniform size—clay, sand and gravel. Only glaciers leave heaps of material of all sizes as they scrape down valleys or across the land like giant bulldozers. Even the debris left by glaciers may be sorted later by running water.

Sooner or later the material formed by the destruction of rocks is laid down in beds of sediment. This is buried deeper and deeper by the layers of each succeeding year until the heat, pressure and cementing substances bind the material again into sedimentary rock.

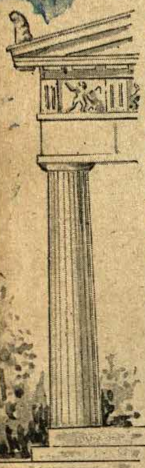
Deep in the earth the sedimentary rocks may be changed into metamorphic rocks, or they may be in a melted form and so spewed out again as igneous rocks. Sometimes the mountain-making forces push layers of sedimentary rocks up into new mountains. Then the forces of destruction start work anew and the endless process is repeated.

Both the destruction of rocks and the formation of new ones are very slow processes. Yet scientists say that large beds of sedimentary rocks many thousands of feet thick have been formed and that mountains that once were thousands of feet high are now mere rounded hills. It is easy to understand that the earth must be very old, when we consider how much has happened as a result of the rock cycle.

How do we use rocks?

Nothing on the earth is more durable than rocks. Even though rocks are continuously destroyed, they are changed much less rapidly than other materials, such as wood. Man learned this long ago, so he has used rocks for building all kinds of structures which he wished to last many years. In addition, rocks do not burn.

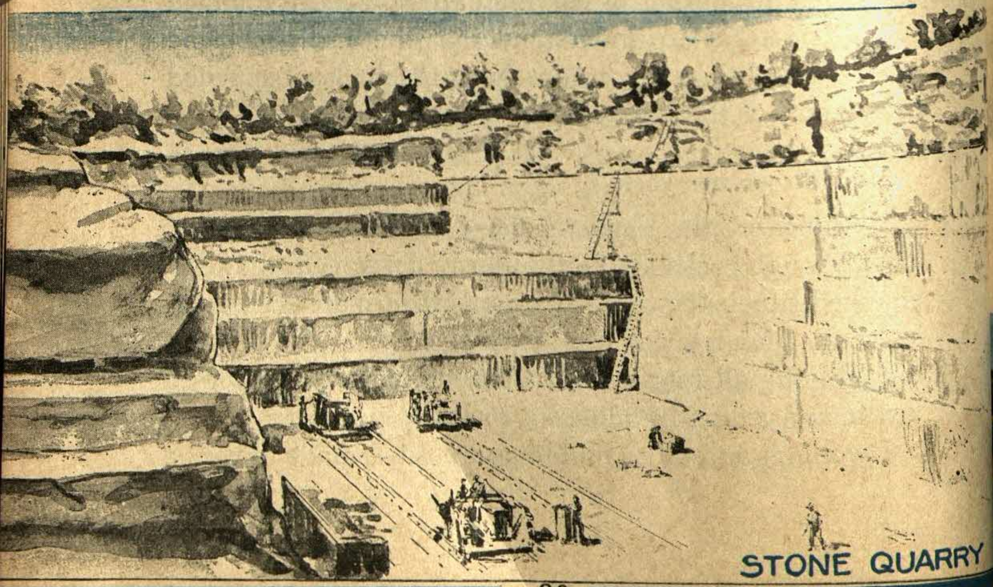
Dwellings and other buildings are often made of rocks.



The Eskimos build crude houses by stacking stones in a crude fashion. Much more shapely and useful buildings are made by holding stones in place by the use of mortar. If stones are split or cut into blocks of regular shape and size, it is still easier to build structures. All civilized peoples have learned to cut stones into blocks which can be used for building purposes. The Great Pyramids of Egypt, the beautiful buildings of ancient Athens and Rome and the remarkable temples of Central and South America are examples of structures made from stone.

Certain rocks are better suited for making buildings than others. Granite is very hard and resists destruction. In addition, it is found in many colors and in many patterns due to the sizes and kinds of crystals of which it is composed. Granite is quite expensive to use because it is too hard to be cut easily into the proper shape.

There are many varieties of marble, which differ in



STONE QUARRY

color and in pattern. Marble is much used for the interiors of fine buildings. Some kinds of marble resist the weather well enough to make them suitable for making the outside of buildings and for use in monuments.

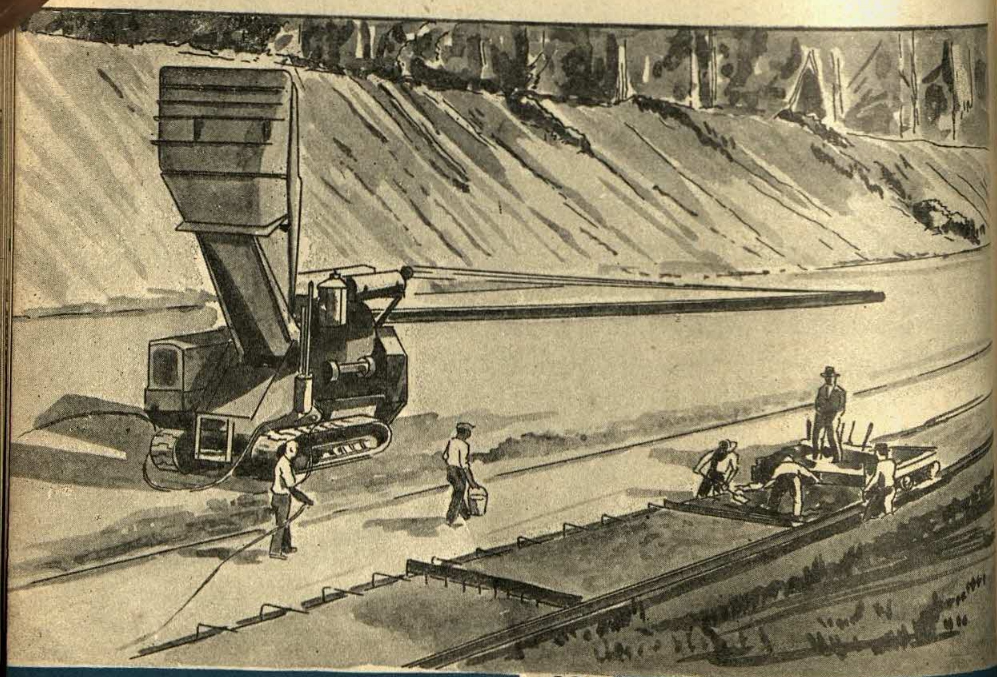
There are some kinds of limestone and sandstone that can easily be split into sheets or blocks along the lines of their layers. They are usually somewhat porous. Water may soak into the pores. If the water freezes, it breaks the rock. Some kinds of both rocks are used for building purposes. At one time, a kind of red sandstone, called brownstone, was used in large amounts in building the fine homes in big cities.

Sandstone is not easily polished to a smooth surface since it is made of grains of sand cemented together. Its roughness gives sandstone an important use in making grindstones of various sizes and shapes. They are used for smoothing metals, sharpening tools, and even in grinding grain into meal, and wood into pulp for making paper.

The long-lasting, fireproof qualities of building stones are so desirable that it is unfortunate that they are too expensive to be used for many purposes. The expense is due to the difficulty of cutting and shaping them. Many years ago, it was discovered that certain materials when mixed with water would harden into a kind of artificial stone. These are called hydraulic cements. The Romans used such a cement made partly from volcanic ashes. The hydraulic cement used today is made by

heating a mixture of clay and limestone and then grinding the product to a fine powder. This material is Portland Cement. More commonly we call it "cement." The cement is mixed with water, sand and small stones or crushed rocks, and while still wet the mixture is poured into forms of the desired shapes. After a time, the sticky, wet mass hardens into a solid rocklike mass called *concrete*. Like natural rocks, it is hard and fireproof, but brittle. Sometimes concrete is strengthened by burying steel rods in it, forming reinforced concrete.

If we did not have this remarkable concrete, it is very doubtful that we could build great dams and power stations. It is used in making roads. Foundations, floors, even entire buildings are made from it. Ships, also, have been made of concrete.



The Record in the Rocks

The school bus turned down a narrow country road. Soon it reached a big farmyard. "All out!" called Miss Brooks, the teacher, as the bus halted. The boys and girls hurried out eagerly.

"Jack has the rope. Here are six geological hammers. Harry, will you take charge of them? Let's go." She thanked the farmer for allowing them to cross his property. Then she led the way, up the lane, around a plowed field, into woods thick with underbrush. Soon they came to a steep bank. Forty feet below flowed a creek. Fred helped Miss Brooks tie one end of the rope securely to the trunk of a tree. James scrambled down the slippery bank taking the other end and securing it to a tree at the bottom. Then everyone went down safely holding onto the rope.

"Oh, boy, is this fun!"

Once down, the fossil hunt was on.

"I see a squid pen," said Bob.

"Who doesn't? Look at them everywhere."

Evidently squids must have been common in the sea that once covered the land at this spot. Brown cigar-shaped fossils of all sizes littered the place.

"Look at this big shell," said Miss Brooks. "Here, Bill, let me have the hammer." The teacher showed them how to wedge the shell out of the marl bank into which it was cemented. It came out, almost perfect.

"Look at this cast. And here is a snail shell. What a tricky coil!"

"Isn't this a perfect little pair of shells?" Mary held up a tiny ridged specimen the size of a fingernail.

"Are these any good?"

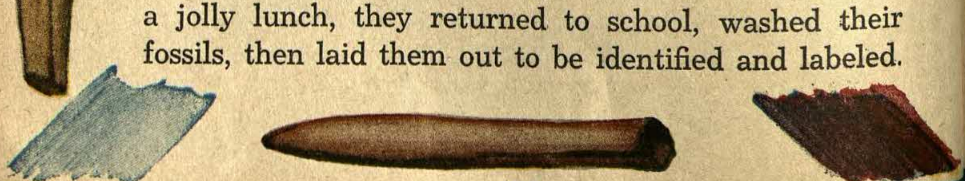
"Yes, they're worth keeping. That fragment is a bit of fossil scallop. You'll not find a whole shell. The other one is a piece of an ancient oyster shell." Before coming, the boys and girls had handled samples of different fossils which had been taken from this same place by other classes on previous trips.

"Doesn't it seem queer that there are no fossils at any other place in this creek, that we had to come sixteen miles to just this little spot to find them?" asked Mary.

"Well, this is probably the best," said Miss Brooks.

"Do we have to go already? May I be the last one up the rope?"

Reluctantly the boys and girls left their hunt. After a jolly lunch, they returned to school, washed their fossils, then laid them out to be identified and labeled.

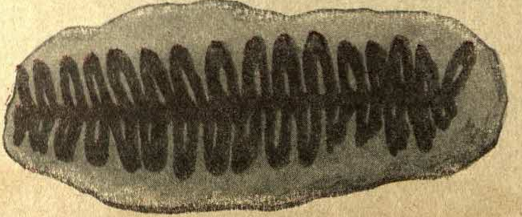


How do rocks tell a story of the living things of long ago?

Some rocks are like the leaves of a book from which we can read the history of living things on the earth. Embedded in these rocks are the remains, impressions or traces of plants and animals that lived in past ages. These evidences of past life are called fossils. Unless the rocks have been disturbed, the oldest rocks are at the bottom, the most recent at the top. Geologists read the story from bottom to top, from the oldest rock to the most recent.

Not all the parts of animals and plants have been preserved. When animals are buried in mud or sand, the soft parts of their bodies usually decay. Only the hard parts remain to become fossils. The shells of mollusks, the bones and teeth of reptiles and mammals, the scales and bones of fish are actual parts of animals which have been preserved. Sometimes shells or bones buried in sand or clay remain almost unchanged for many years. Then the shell or bone is replaced by mineral substances. They become petrified. Sometimes the inside of a shell is filled with minerals, making a cast which shows the internal markings of the shell. The skin of animals is preserved only rarely.

Sometimes only the traces of an animal are found,



FOSSIL FERN

such as the tracks of a reptile that were made in sand or mud before it became stone.

The impressions of plant parts are found in rocks where leaves or stalks became buried in mud, leaving the print of the plant when the mud hardened into stone. Woody stems of plants may become petrified, that is, the wood fiber is replaced by minerals such as silica.

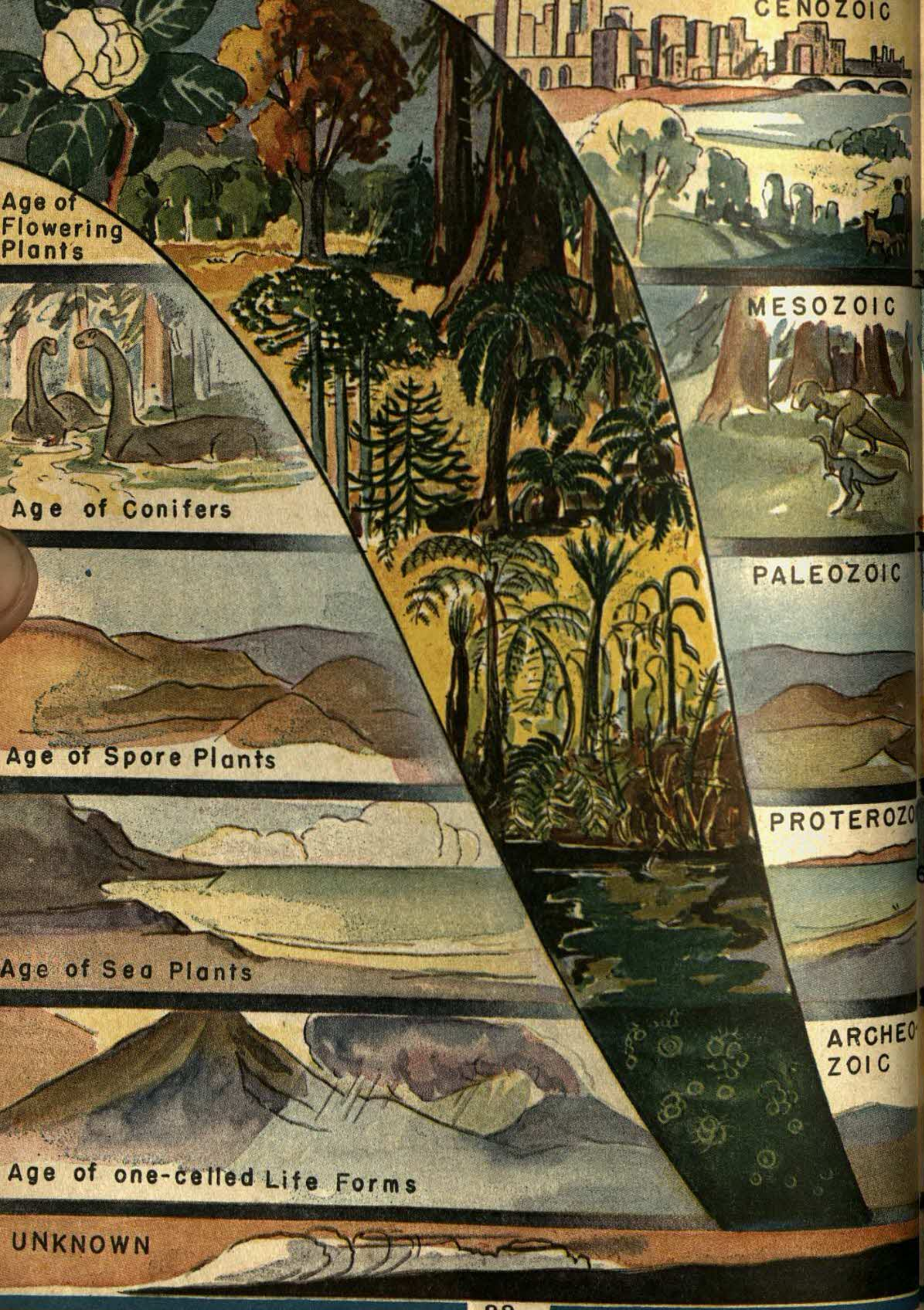
Fossils show us the shape, size and general appearance of the living thing which they represent. The entire shell of a mollusk may be present. Sometimes a tooth or only a few bones of an animal are found. The form of some coral masses is so perfectly preserved that the internal structure can be seen. The luster of the inside of a mollusk shell may still be present. Sometimes an understanding of the habits of an animal can be gotten from its fossil. Fossil "shipworms" are found petrified in the wood in which they burrowed. Pieces of fossil ferns have been found which are like those that now grow in wet woods and swamps. This tells us something of the plants which fossilized to form coal many thousands of years ago.

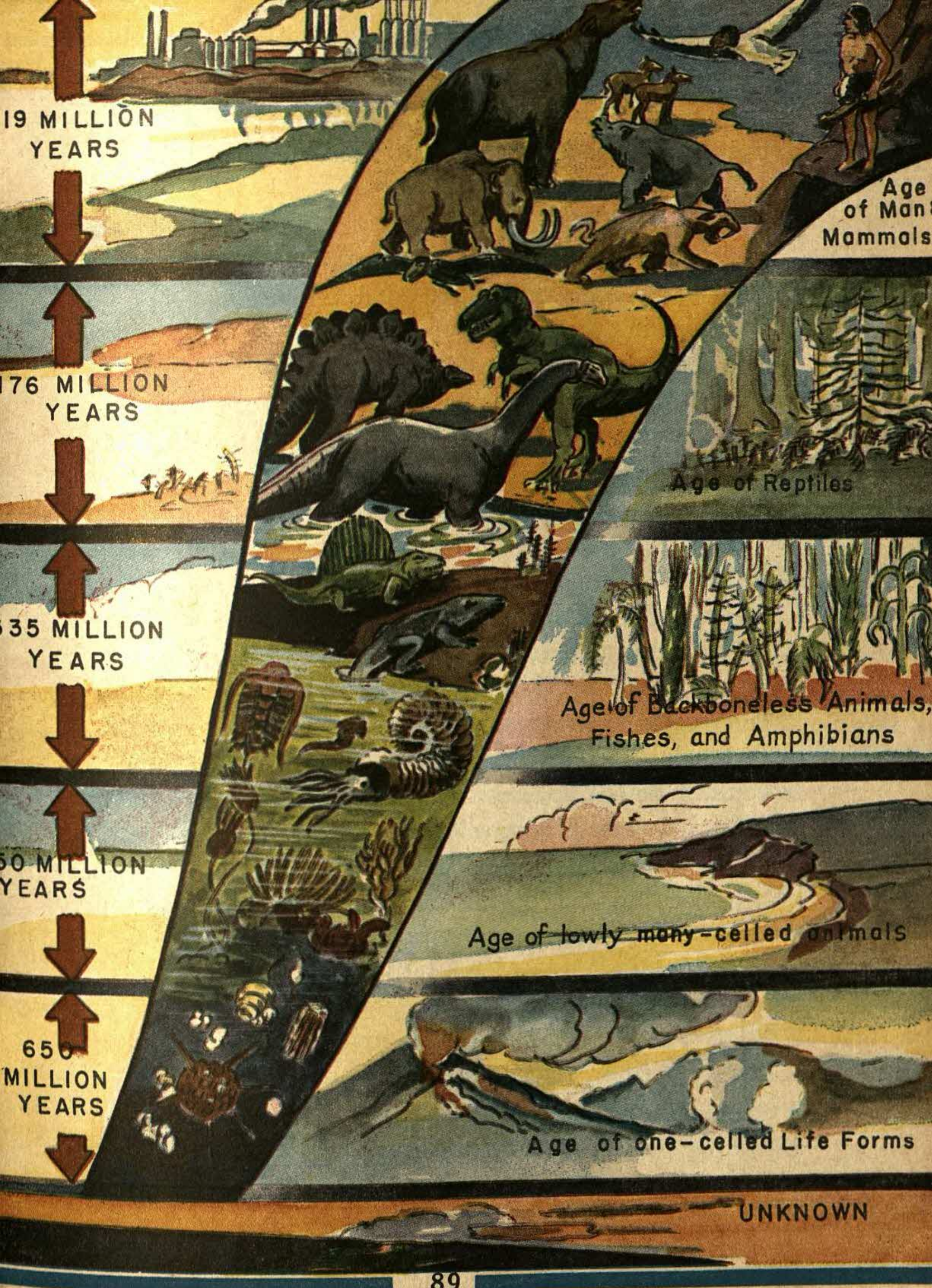
You may wish to know whether fossils can be found in your own neighborhood. A record has been made of the rocks in almost every region in the United States. Geologists know where to look to find fossils. Many of them are found in quarries and other excavations and wherever we can uncover sedimentary rocks, such as limestone, shale, marl and sandstone. There are fossils preserved also in other substances. Insects have been found in the hardened resin of trees, which is called amber. In southern California, many animals fell into

INSECT FOSSIL IN AMBER

tar pits to which they came for drinking water. The tar preserved their skeletons. In the frozen wastes of Siberia, elephant-like mammals have been discovered in the frozen mud below the surface of the earth.

Collections of local fossils can be seen on exhibit in many museums of natural history. Collections from everywhere are on display in museums such as the American Museum of Natural History in New York or


CENOZOIC
Age of Flowering Plants
MESOZOIC
Age of Conifers
PALEOZOIC
Age of Spore Plants
PROTEROZO
Age of Sea Plants
ARCHEO-ZOIC
Age of one-celled Life Forms
UNKNOWN


19 MILLION YEARS
Age
of Man
Mammals
176 MILLION YEARS
Age of Reptiles
35 MILLION YEARS
Age of Backboneless Animals, Fishes, and Amphibians
50 MILLION YEARS
Age of lowly many-celled animals
650 MILLION YEARS
Age of one-celled Life Forms
UNKNOWN

the Field Museum of Natural History in Chicago. Here we can see also the kind of surroundings in which these living things of the past spent their lives.

How old is the earth?

No one knows just how old the earth is, but scientists have several ways of estimating its age. One method is to determine the amount of salt in ocean water today and to divide that by the amount of salt which is being carried to the oceans each year by rivers. Such calculations show the earth to be many million years old; but, for many reasons, these results are not at all exact.

Another estimate is obtained by dividing the total thickness of sedimentary rocks, laid down during the entire earth's history, by the rate at which sediments are being formed today. This calculation shows the earth to be several hundred million years old. Again, this estimate is not too reliable.

The most accurate method found to date is based on a study of rocks containing the chemical element, uranium. Scientists know that uranium breaks down at a known rate to form the gas, helium, and lead. If a rock contains uranium and lead, the age of the rock can be found by estimating the time needed to produce the amount of lead present. Using this method, the earth is considered to be over two billion years old.

What change has there been in the kinds of living things as time went on?

Geologists have divided the history of the earth into a number of periods or ages. The number of years each era lasted is not known exactly, but many estimates have been made. If the earth is two billion years old, each period must have lasted millions of years. Probably more than half of the total time passed before living things appeared.

The first living things must have been plants, since all animals depend on plants for food. The simplest animals were probably only bits of living matter in the water. Some scientists believe that certain kinds of bacteria were among the first living things. Blue-green algae are simple plants which appeared on the earth a very long time ago. Some forms of these algae live in the waters of the earth today. Early plants had no true roots, stems, or leaves. For millions of years these ancient plants, along with simple animals, lived in the waters which covered the earth. Sponges, corals and jellyfishes, worms, trilobites and many kinds of shell-bearing mollusks were present. There were probably many others whose soft bodies were not preserved in the rocks to tell the story of their existence.

We do not know exactly how or when or where life first began on the earth. We do believe that all living things which have existed and which exist now have come from the first forms of life. Many modern plants and animals are quite different from those of earlier times. Just how living things of today became different from those of earlier times is not easy to understand. One explanation is that all individuals of a certain kind of living things are not exactly alike. Thus, some individuals are better fitted to their environment. These are more likely to live and to produce offspring. Those which are not so well fitted to their environment are more likely to die. Over very long periods of time, this process could produce kinds of living things quite different from their early ancestors.

The study of fossils tells us that certain kinds of living things which were once common on the earth are now extinct. They may have disappeared because they were not fitted to their environment.

We cannot describe all the many kinds of plants and animals which lived on the earth during the different ages, but we can mention some of the important changes in the kinds of living things. All the early animals were without a backbone and are called invertebrates. The first animals with backbones, or vertebrates, were fishes. They were very different from our fishes of today. They had a covering of bony plates which looked like armor. This period of the earth's history is often called the "Age of Fishes." Fishes like those of today appeared later and were quite common in the Coal Age.

Another important event in the history of living things took place when some of them came out of the water to live on land. Probably a liverwort, a relative of mosses, was the first plant to live successfully on land. Of the animals, a scorpion was perhaps the first invertebrate to adapt itself to breathing air and to living on land. Other invertebrates followed, among them insects of many kinds, some much larger than any on earth today. The first backboned animals to adapt themselves to living on land were the amphibians. The early amphibians were larger than any of our present-day toads, frogs and salamanders.

Later, reptiles appeared. They were found in great numbers during one period of the earth's history, now called the "Age of Reptiles." Some of these reptiles lived in the seas, others in swamps, still others on the dry land. All of them breathed by means of lungs. Dinosaurs were among the many kinds of reptiles of that age. Some dinosaurs were larger than an elephant, and some no larger than a chicken. Some were plant-eaters; some were flesh-eaters. Even the largest of the dinosaurs had very small brains. For reasons that are not clear, dinosaurs disappeared from the earth about sixty million years ago. Many other kinds of reptiles are still to be found among the living animals of today.

The first mammals appeared during the Age of Reptiles. These mammals were small but warm-blooded. Later, there came larger and more intelligent mammals which in turn dominated the earth.

The first fossil bird was found in a German quarry in the rocks of the Age of Reptiles. It is called *Archeop-*

teryx. This bird was about the size of a crow and had teeth in its jaws. No modern birds have teeth.

During the Coal Age, the dominant trees were club mosses, horsetails and ferns. Some of these grew 75 feet high. These plants reproduced by spores. Growing along with them were plants called seed ferns, the first plants to reproduce by seeds. Seed ferns ceased to exist, but other seed plants came later. Now seed plants are the most numerous plants on the earth. Modern club mosses, horsetails and ferns are very small compared with their ancient relatives and with the largest seed plants of today. The huge ferns, horsetails and club

mosses of the Coal Age were some of the plants whose remains were changed into coal.

The history of living things is a long, interesting one. More facts are constantly being added to the story as new fossils are found. Scientists who study these facts carefully, point out that there has been a steady development from simple to more complex plants and animals.

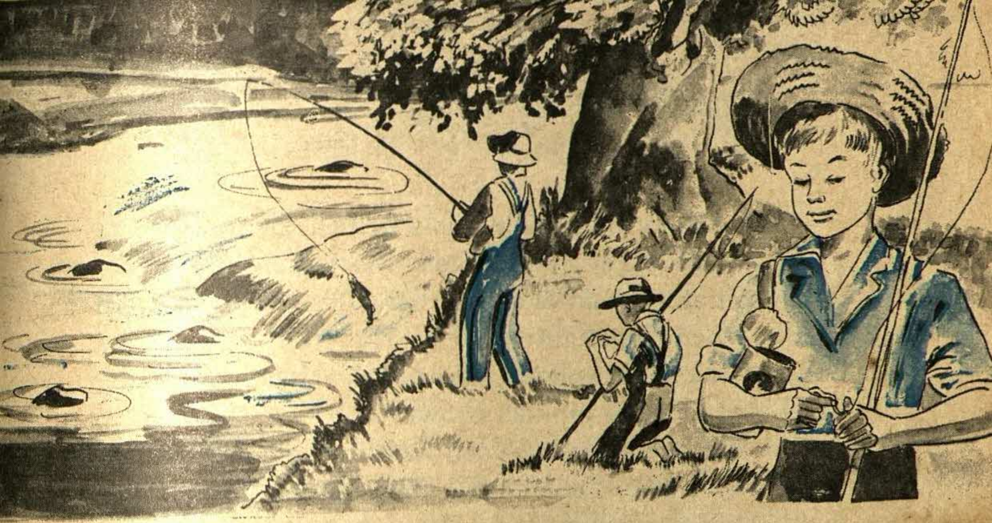
When did man first appear on the earth?

In rocks of the period in which great glaciers covered the land about a million years ago, fragments of skulls, jaws and teeth have been found. These are considered by many to be the remains of ancient men. They have been found in widely scattered places, such as China, Java, England, Germany and France. Experts have built up entire skulls from the fragments. These restorations bear such names as the Peking Man, the Java Man, the Piltdown Man, the Heidelberg Man and the Neanderthal Man. There is evidence to show that the Peking Man knew how to use fire, and how to use stones as tools. The lower jaw of the Heidelberg Man had teeth more nearly like those of modern man than did any of the others. In the rock caverns where the remains of the Neanderthal Man were discovered, stone hunting implements were also found.

When the last of the glaciers spread over Europe, the Neanderthal Man disappeared. Fossils show that a more

intelligent group, called the Cro-Magnon Men, took the place of the Neanderthal Men. They were named from the cave in France where one of the first skeletons was found. The Cro-Magnon Men were large, at least six feet tall. Their features were very much like those of modern man. They were hunters and wandered wherever food was to be found, living in rocky caverns. The Cro-Magnon Man was gradually replaced by other men who may have moved into Europe from the south and east. These newcomers may be the ancestors of modern man.

It is believed that man first appeared on the earth about a million years ago. This is shorter than the time that plants and animals have lived on the earth. A million years is not very long when compared with the age of the earth, which is about two billion years.



The Changing Soil

Bill and John were spending a month on their Uncle Henry's farm. One day their uncle suggested that the boys go fishing in the brook which ran through the pasture.

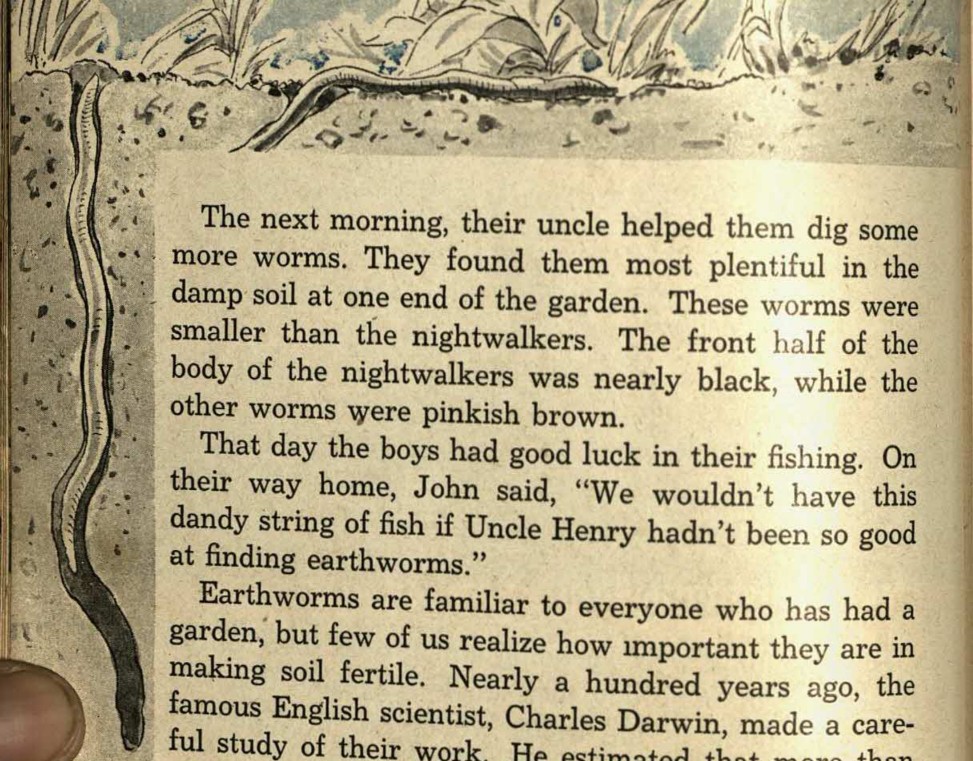
"You'll need some worms for bait, boys. After dark we'll try to catch some nightwalkers."

Armed with flashlights and a tin can, they searched through the flower beds.

"There's one, boys."

A dark line showed dimly among some dead grass. With a quick motion, Uncle Henry seized the dark object and carefully pulled out a worm.

"They come partly out of their burrows at night, keeping the end of their bodies in the burrow. Unless you grab quickly, they will pull themselves back out of danger."



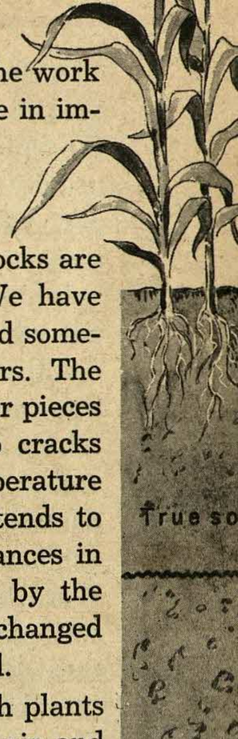
The next morning, their uncle helped them dig some more worms. They found them most plentiful in the damp soil at one end of the garden. These worms were smaller than the nightwalkers. The front half of the body of the nightwalkers was nearly black, while the other worms were pinkish brown.

That day the boys had good luck in their fishing. On their way home, John said, "We wouldn't have this dandy string of fish if Uncle Henry hadn't been so good at finding earthworms."

Earthworms are familiar to everyone who has had a garden, but few of us realize how important they are in making soil fertile. Nearly a hundred years ago, the famous English scientist, Charles Darwin, made a careful study of their work. He estimated that more than 53,000 earthworms may live in an acre of garden soil. They make burrows which reach from the surface deep into the soil. Air and water get into the soil through the burrows. Also, earthworms eat soil. As it passes through their bodies, bits of plant material are used for food, while the particles of soil are ground up and acted upon by digestive juice. At night, earthworms come to the surface of the ground. They bring with them some of the soil which they have eaten and leave it as castings on the surface. They may drag bits of leaves into their burrows. In these ways, they slowly enrich the soil. Darwin estimated that ten tons of soil may be eaten every year by the earthworms in an acre of ground. The work of earthworms in the soil is of the greatest value in improving it for farming.

What is soil?

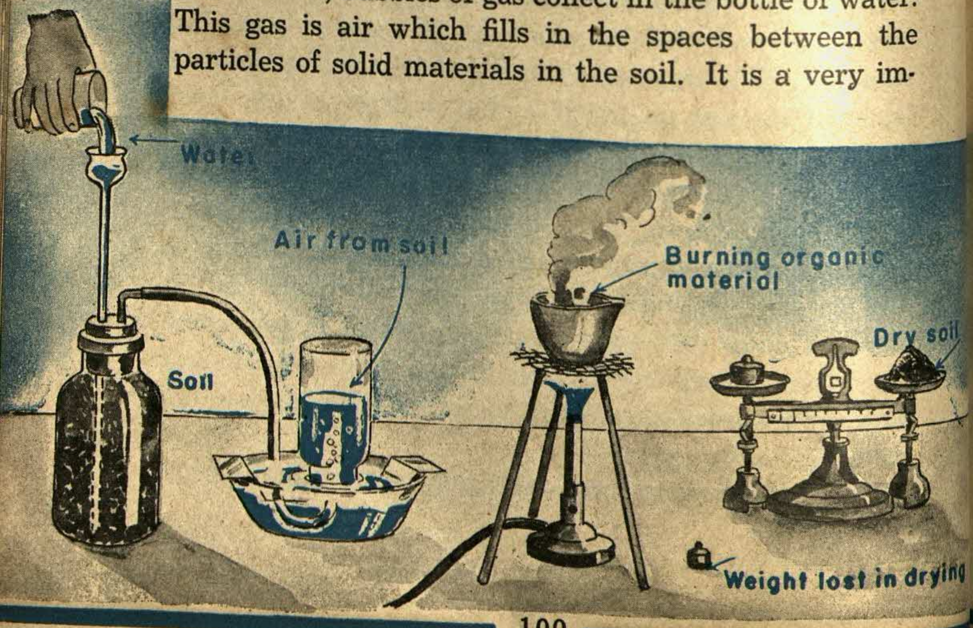
We have already studied the ways in which rocks are broken up into smaller and smaller pieces. We have learned how the pieces of rocks are scattered and sometimes sorted by wind, running water and glaciers. The broken rock is crumbled into smaller and smaller pieces in many different ways. Water may seep into cracks and freeze, thus splitting the rock. As the temperature changes, the rocks expand and contract. This tends to break them into smaller fragments. The substances in the rocks may be changed to new substances by the action of water and air. Eventually the rock is changed into a mass of fine particles which we call soil.



Soil is the part of the earth's surface in which plants can grow, provided there is enough moisture, air and sunshine. We can understand soil best by studying a layer of it. Let us imagine that a ditch is dug deep enough to expose the rock which everywhere is found under the earth's surface. This is called *bedrock*. The layer above bedrock is not all alike. Near bedrock it consists of broken stones which evidently came from it. Higher up, the material is still more broken and in smaller pieces. Its appearance shows that it, too, came from the bedrock but has been acted upon for a longer time by the rock-destroying forces. This layer is often called the *subsoil*.

The upper part of the earth's surface is quite different from the subsoil. Ordinarily it is darker in color, due to the presence of some decayed plant and animal material. We call this organic material. This dark layer, which is usually only a few inches thick, is true *soil*. It is the part which we overturn when we spade a garden or plow a field.

In the soil, there are four important parts. Let us find out what these parts are by experiments. Fit a wide-mouthed bottle with a two-hole rubber stopper in which there are a thistle tube and a bent glass tube with rubber tubing attached, as shown in the diagram. Rest the small end of the thistle tube on the bottom of the bottle and pack the thistle tube full of fresh garden soil. Slide the stopper down until it fits tightly in the neck of the bottle. Place the end of the rubber tube under the bottle of water in the pan. Now pour water into the thistle tube until the soil is completely saturated. As water soaks into the soil, bubbles of gas collect in the bottle of water. This gas is air which fills in the spaces between the particles of solid materials in the soil. It is a very im-



portant part of the soil, for it furnishes oxygen to aid in the decay of organic materials and it makes it possible for earthworms and a host of other animals and plants to live there.

Let us weigh carefully a cupful of soil fresh from the garden. Then spread it in a thin layer on a plate. Keep it over a radiator or in the sunlight until it is thoroughly dry. Weigh it again. The weight lost is due to evaporation of water. Water is the second important part of the soil. We know that no plant or animal life can live without it.

After the dry soil has been weighed, heat it very hot for a half hour in a shallow metal dish. As it is heated, you will notice smoke rising and the smell of something burning. Stir the soil several times so that all parts are exposed to the air. In this way the organic material is burned up. When you are sure that no further burning will take place, let the soil cool and weigh it. The loss of weight is due to the burning of the organic material, which is the third important part of the soil.

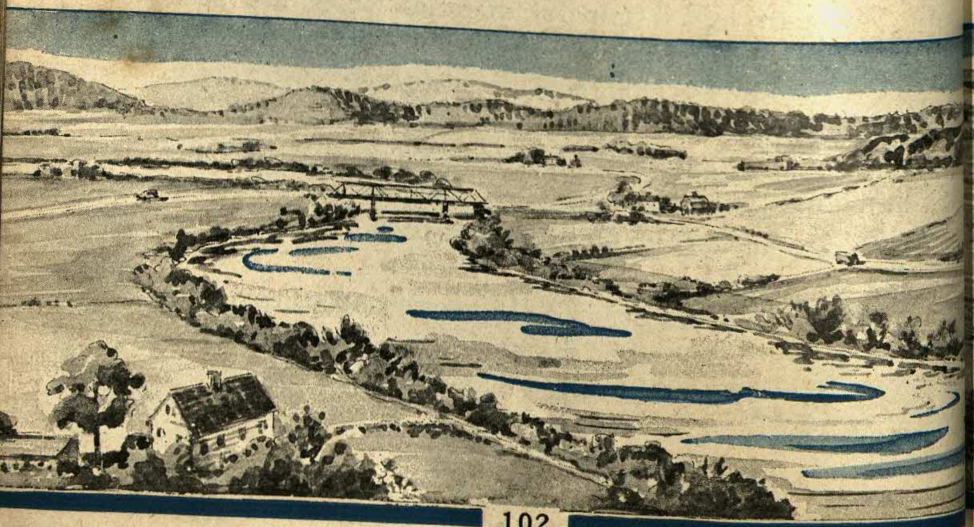
The part left is mineral material which has been formed by the destruction of rocks. We must not think of the minerals as being just crushed rocks. Many of the substances in the original rocks have been changed by the action of air, water and bacteria so that they are quite different. The process of change which has made new substances from the original rocks is called *weathering*.

Soil is the topmost layer of the earth's surface, and is composed of weathered minerals from the rocks, mixed with air, water and organic materials.

What are the different kinds of soil?

One way of describing a soil depends upon its mode of origin. Soils that are found directly above the rocks from which they are derived are called *residual* soils. In many places, the soil has been brought from other places. Such soils are called *transported* soils. Rivers, especially when flooded, carry great amounts of sediment. The sediment is deposited where rivers overflow their banks, forming what is known as *flood plains*. Most large rivers have flood plains, especially near their mouths. In the Mississippi River Valley, the flood plain is 20 to 75 miles in width and stretches from the Gulf of Mexico northward for about 500 miles. The flood plains often have deep soil built up a little at a time over hundreds of years. If flood plains are not swampy, they make excellent farm lands.

A good deal of sediment may be carried by large rivers to their mouths. As the river water flows into the ocean, the sediment is deposited, gradually building a delta. A study of the map of Louisiana shows that the land

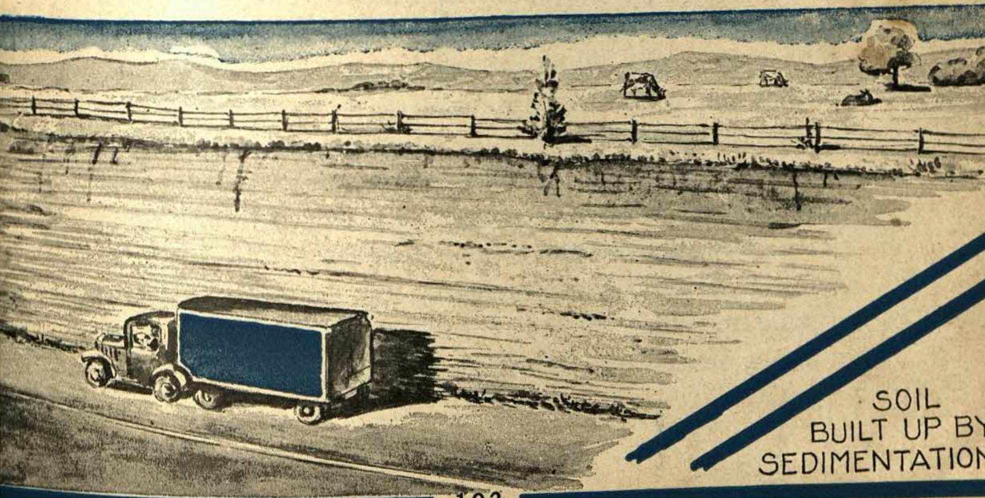


around the mouth of the Mississippi River projects far out into the Gulf of Mexico. This projection has been formed by the sediment brought down by the river. Delta soil is very rich for farming but is often swampy, since the land does not rise much above the level of the river.

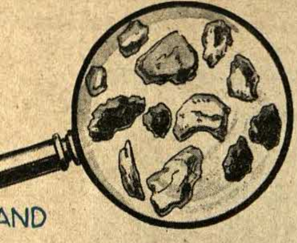
There are large areas along the coasts of the Atlantic Ocean and the Gulf of Mexico where the land has been raised from the sea bottom by earth movements. The land is quite flat and the soil is sandy. When properly cultivated, it makes good farm land.

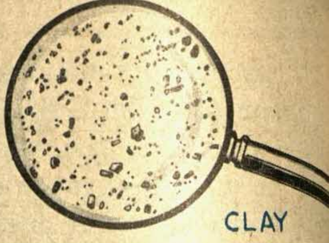
Wind-blown sediments sometimes form a kind of soil which is known as *loess*. Loess soil is found in large areas of Nebraska, Iowa, Missouri, Illinois and Kentucky, as well as in several other states. The soil is made of very fine particles. Some of the finest farm lands are located on loess soils.

Soils may be classified on the basis of the sizes of mineral particles composing them. Soils which have been formed from material left by glaciers usually have



SOIL
BUILT UP BY
SEDIMENTATION

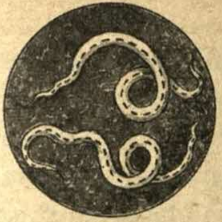




stones of all sizes in them. Such soil is gravelly. When about three-quarters of the soil particles are sand, the soil is called sandy. Scientists consider that particles are sand if they are between one twelve-hundredth and one-twelfth of an inch in diameter. In some soil, a large portion of the particles are much smaller than sand. Clayey and adobe soils are made of very fine particles.

All sorts of mixtures of gravel, sand and clay are also found. One important mixture is loam. It has both sand and clay particles in quite large amounts. A loam soil makes good farm land, for this soil has some of the good qualities of both sandy and clayey soils and not so many of the bad qualities. Sandy soils are so coarse that water drains through them quickly, but they allow air to enter freely. On the other hand, clayey soils become very sticky when wet and very hard when dry. Neither air nor water circulates through them easily. Loam holds water enough for plant growth, but also is coarse enough to allow air to enter.

A rich soil must have organic material in it. In fact, a rich soil cannot be formed without the action of living things to bring about changes in the minerals and the organic materials. Most of the organic materials consists of roots, leaves and other parts of dead plants which



NEMATODES

have been mixed into the soil. There are also the remains of dead animals. The material is more or less decayed by the action of bacteria, molds and other simple living things. Such material is called humus. Its brown color causes the topsoil to appear darker than subsoil. Dry soils on high land usually have from 2 to 5 per cent of humus. In swamps, plants grow abundantly and produce much humus when they decay. Swamp soils contain more than 5 per cent of humus.

MOLDS

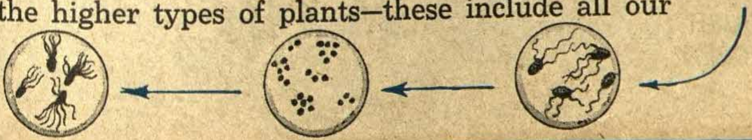
Humus is a very important part of the soil for farming purposes. It helps to hold water, it furnishes the food for the living things which keep the process of forming soil going on, and it furnishes food materials for plants.

What does the soil furnish to living things?

Our study of the soil has shown us that it is a thin layer, at most a few feet thick—often only a few inches. Yet it is this thin layer of soil, covering most of the land surface of the earth, that grows all the common plants that furnish us food, clothing and lumber. Both man and his domestic animals, as well as a host of other living things, are almost entirely dependent upon the soil.

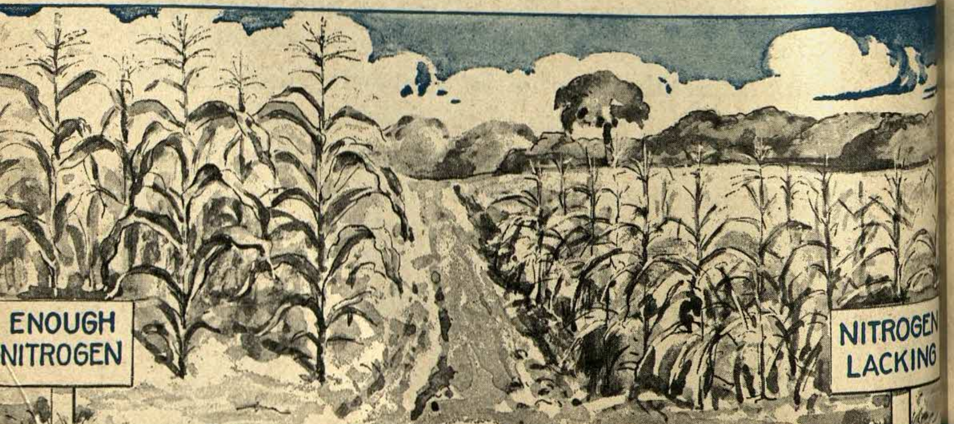
SOIL BACTERIA

All the higher types of plants—these include all our



common food plants—need light, heat, air, water, nutrients, and support to hold them in place so that they can receive the sunlight. The soil helps to supply all of these except light. Roots penetrate the soil and the plant is anchored in place and supported. Water is taken from the soil by the roots. Part of the air needed by the plant comes from the soil. The soil becomes warmed by the sun's rays and so provides part of the warmth needed for the growth of plants. All the mineral substances used by plants come from the soil.

Carbon, hydrogen and oxygen—all obtained from water and carbon dioxide—make up over nine-tenths of the weight of plant materials. The remainder consists of at least eleven substances, each in small amounts; yet all are necessary if plants are to grow properly. Nitrogen, phosphorus, potassium, calcium, magnesium and sulphur are used in larger amounts than the other five, which are iron, manganese, boron, copper and zinc. Each of these can be obtained by plants only from the soil. If one or more of these elements is lacking, good crops cannot be grown.



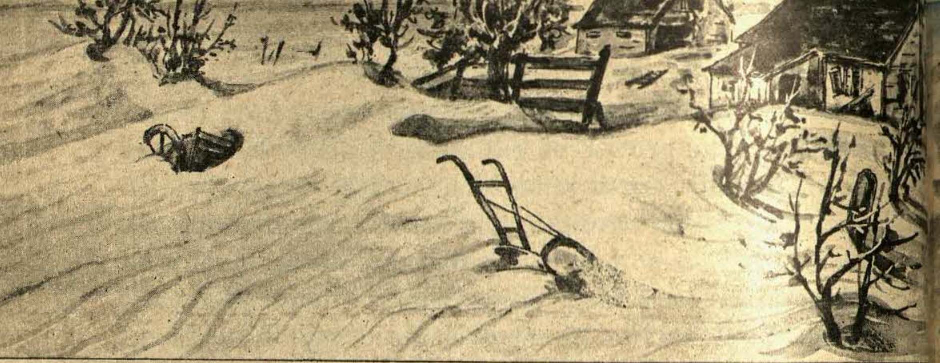
How may soil be made less useful to man?

Before men began to grow crops, every kind of soil supported the growth of the kinds of plants best suited to it. Usually many kinds of plants grew mingled together, each one taking from the soil certain substances which it needed and very often supplying humus or other things needed by other plants. Under these conditions, soil did not become changed rapidly, at least it did not become poorer in quality.

When farming began, plants were cleared from the land in order that the farmer might grow the kinds which he needed for food. Usually, whole fields are planted to one kind of crop. Sometimes the same kind is planted year after year. The growth of one kind of plant in large numbers on a piece of land takes the plant nutrients from the soil much faster than they are restored by the slow processes of soil making. Very soon the soil becomes poorer because some of the substances needed for plant growth have been used up.

Long ago, farmers learned that it was necessary to add to the soil certain substances which were taken out more rapidly than others. Potassium, nitrogen and phosphorus are most rapidly used up. Manure and other fertilizers are added to make up for the loss.

In dry sections of the United States, the natural vegetation is adapted to the rainfall received. When the land in these dry areas is plowed, the natural vegetation is destroyed. The crops planted, like wheat or corn, may take more water from the soil than did the natural vegetation. If this happens, the soil may become so dry that the wind can blow it away. During the early



1930's, there were several seasons in which there was less than normal rainfall in a belt of land east of the Rocky Mountains. So much of the soil blew away that the region became known as the Dust Bowl. Some of the land lost so much soil that it was seriously damaged. In dry regions, farmers must use special methods in order to preserve the soil.

The most serious destruction of soil comes from erosion by water. When rain falls on plowed sloping land, part of it runs off, carrying particles of soil. As the water runs off, it forms little trenches. In heavy rains, these little trenches may grow into large ones, forming gullies. Once gullies are formed, every rainstorm makes them larger. Careful measurements of the amount of soil carried away by running water have shown that as much as 40 tons of soil may be removed in a year from one acre of plowed land. At this rate, it does not take many years for the thin layer of true soil to be entirely removed.

In the United States, thousands of farms have been completely destroyed by erosion. In place of farms which were once able to grow fine crops, there is now

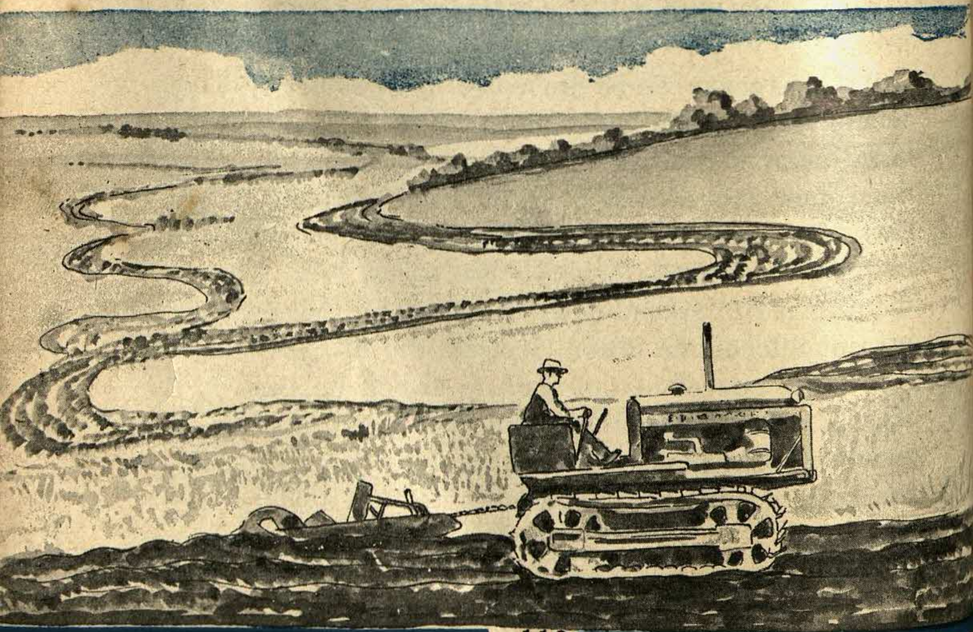
nothing but deep gullies which grow deeper and longer with every rainstorm. Not only does erosion destroy farms, but the sediment is carried into rivers and here it fills up the channels, thus making it easier for floods to develop.

How can soil be conserved?

Water erosion can be prevented in a number of ways. Whenever possible, land should not be left bare. It has been found that erosion from grass-covered land is less than one-hundredth as great as that from bare plowed land. On slopes, it is often desirable to plow the land in strips with grass between the strips. The furrows should not run up and down the slope, for that provides natural ditches for water. Instead, the furrows should follow the curves of the land, as shown on page 110. This is called contour plowing. On steep hillsides, it may be necessary to make terraces, which are flat places, like steps, from which water does not run quickly.

After gullies start to form, dams made of bushes or other materials will prevent the water from flowing rapidly and aid in catching sediment. Plants that will grow on steep slopes should be planted. This is the best means of preventing water erosion. Not only do the plant stems and leaves retard the flow of water over the surface, but the roots bind the soil together so that it is less easily washed away. It is bare soil which erodes rapidly, not soil on which plants are growing.

The formation of Dust Bowls can be prevented by growing only grass in those places where there is insufficient rainfall to supply regular farm crops with the needed water. In some parts of the Great Plains, trees have been planted in long strips. These serve as windbreaks, which by slowing down the speed of the air near the ground, prevent it from blowing the soil away.



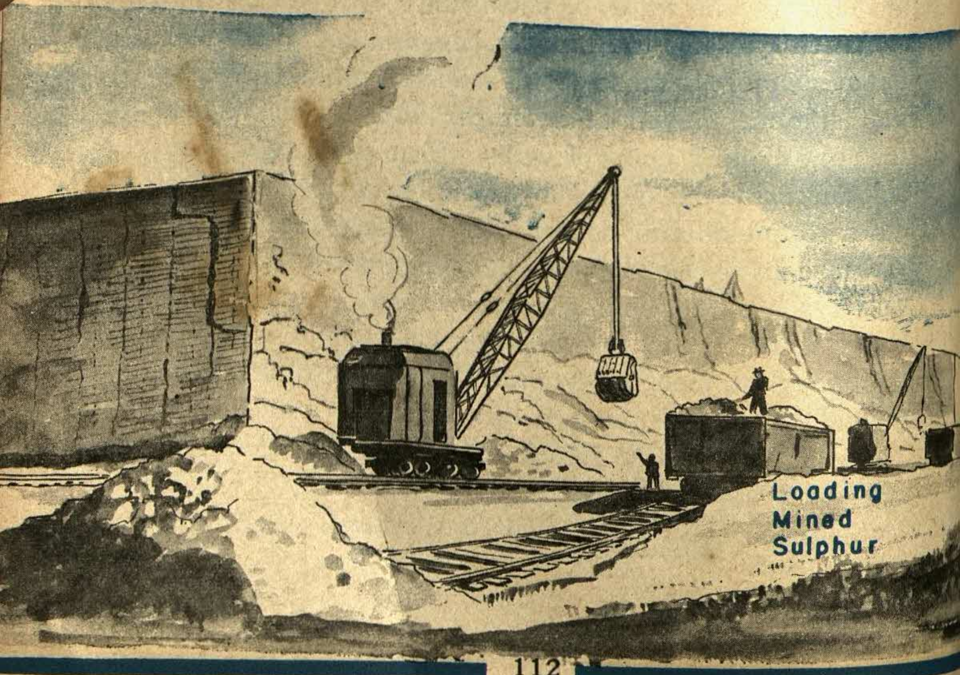
Until about 1900, most of the sulphur used in the world was mined in Sicily. It was known that great amounts of sulphur lay buried not far from the Gulf of Mexico in Louisiana and Texas. The deposits were covered with layers of quicksand, which filled mine shafts as fast as they were dug. All attempts to reach the sulphur by the usual mining methods failed.

In 1891 Herman Frasch heard of the sulphur deposits. For a number of years he had been working with petroleum. He decided that the sulphur could be pumped from the ground much as petroleum is. His friends laughed at him. Chemists and engineers thought that he was crazy. How could solid sulphur be pumped out of the earth like water or petroleum?

Frasch was not the kind of person who would give up an idea just because people made fun of it. He knew that sulphur melted at a temperature a little higher than the boiling point of water. He reasoned that the sulphur could be melted by pumping very hot water down to the sulphur deposits. By heating water under pressure in a closed boiler, its temperature could be raised above the boiling point without changing the water to steam. In this way the water could be made hot enough to melt the sulphur. When the sulphur was melted, it could be pumped like any other liquid.

For several years, Frasch worked on his idea. He secured money and machinery to carry it out. After many discouraging experiences, the first well was drilled, and to the amazement of many people, sulphur was obtained. The method that Frasch used was to drill a well to the sulphur deposit. A six-inch pipe lined the well and kept the quicksand out. Inside the six-inch pipe, a three-inch pipe was placed with a one-inch pipe inside that. Very hot water was forced down the six-inch pipe. This melted the sulphur. Then hot compressed air, forced down the one-inch pipe, caused the water and melted sulphur to flow through the three-inch pipe. The melted sulphur which flowed from the pipe was collected in bins. There it cooled to a solid.

Today the United States produces far more sulphur than any other country because Herman Frasch had an idea and the courage to follow it, in spite of the jeers of people and in spite of great difficulty in getting money and equipment to carry out his plans.



Loading
Mined
Sulphur

What is a mineral?

Anyone who observes rocks and soil carefully soon discovers that they are made up of particles of different substances which vary in color, shape and weight. These separate substances which form the crust of the earth are called minerals. Minerals are always inorganic; that is, they do not include substances which are formed from living things. For this reason, coal, petroleum and natural gas are not correctly called minerals, because they are believed to be made from the remains of living things. However, they form a part of the earth which is very useful to us, so we shall mention them again in this chapter.

Minerals are natural substances obtained from the earth. Coal, stone, iron and silver are a few of the common minerals. Some manufactured substances like glass and steel may have the same composition as minerals. These are mineral in character, but not true minerals, since they do not come from the earth. Minerals have a definite composition; for example, quartz is the mineral making up white sand and always contains 53 1/3 per cent oxygen and 46 2/3 per cent silicon no matter from what part of the earth it comes.

Almost always minerals of a given kind have a definite crystalline shape. This is due to the arrangement of the molecules in a definite pattern. Different minerals have crystals of different shapes, but, as we have learned, crystals always have flat surfaces and straight edges.

Hundreds of different minerals have been discovered. A great many people collect them as a hobby since the

Cullinan Diamond

Cut Diamond

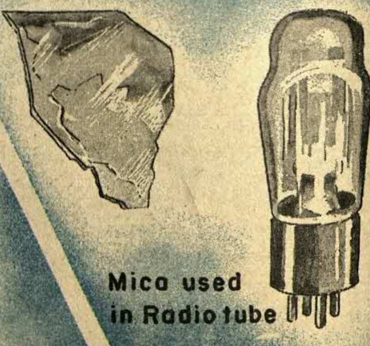
Jonker Diamond

varied colors and crystal shapes make attractive displays. Hunting for specimens takes one outdoors and gives healthful exercise.

There are a great many interesting things about minerals which make it possible to identify them and which sometimes give them important uses. If large crystals are found, it is quite easy to tell what the mineral is. A visit to a museum will be helpful in learning the crystal shapes of different minerals.

The hardness of minerals is an important property. Some minerals are soft enough to be scratched with the fingernail while others are too hard to be scratched with a knife blade. Diamond is a mineral which is the hardest known substance. That is why diamonds are sometimes used for cutting glass. Quartz, in the form of sand, is glued to paper and is used in smoothing wood. Talc is a very soft mineral which can be ground into a fine powder known as talcum.

Quartz used in Sandpaper

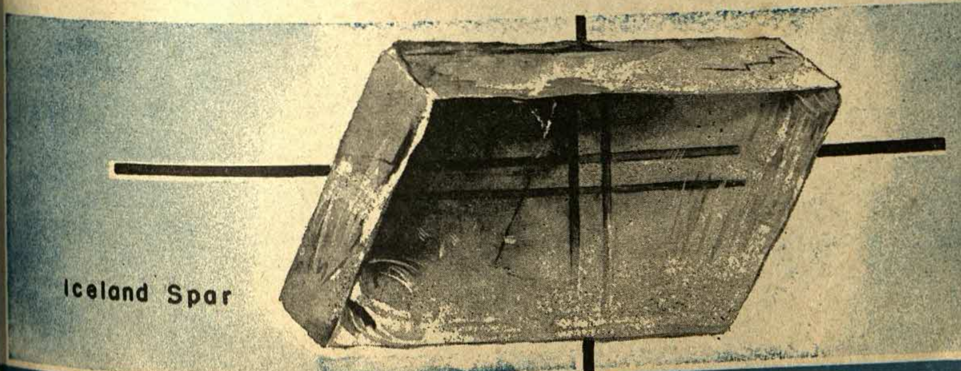

Mica used in Radio tube

A good many minerals can be split easily. Mica can be split into very thin sheets. The sheets of mica have many uses. Sometimes they are used to hold in place the parts of radio tubes and other electrical devices, for mica does not let electricity pass through. Mica can be used as windows in stoves, as it is not destroyed by heat.

Transparent minerals are those through which it is possible to see. Mica is an example of a transparent mineral. Pure quartz is one of the most transparent substances. That is one reason why it is used in making the lenses in some fine microscopes and other scientific instruments. Translucent minerals allow light to pass, but objects cannot be seen through them.

Certain minerals are fluorescent. When light shines on them, they glow brightly. The color is different from the light which causes the fluorescence. In fact, invisible ultraviolet rays cause brilliant fluorescence of a number of substances. Fluorescent electric lights are made by coating the inside of glass tubes with fluorescent minerals. The tubes are made to glow by ultraviolet rays produced inside of them.

When a ray of light passes through certain transparent minerals, it is divided into two rays. Iceland spar is a



Iceland Spar

mineral which shows this property very plainly. When anything is viewed through a clear crystal of Iceland spar, two separate objects are seen.

Of what simple substances are minerals made?

While it is possible to identify most minerals by studying the hardness, color, shape of crystals and other properties, the most certain method is a chemical analysis. In doing this, the mineral is treated in certain ways to separate the various things of which it is made. Chemists tell us that all the thousands of different substances on the earth are made up of nearly 100 simple things. The simple things are called the chemical elements. A few years ago, it was believed that there were only 92 chemical elements. Recently several others have been made. Many chemical elements are found in such tiny amounts that they are never seen by the average person. Some are curiosities, even to the chemist.

A few of the chemical elements are found in the earth

in quite pure form. Most often they are found joined together to make what we call compounds. These are not merely different elements stirred up together. The elements are always found in definite amounts in compounds. Most of the minerals are composed of elements in definite amounts, so they are examples of compounds.

We have already become familiar with some of the chemical elements. Oxygen is the most abundant. It makes up nearly one-half the weight of the outer part of the earth, including the water and the air. Oxygen combines with many of the other elements, but there is so much of it that there is a great amount of it left uncombined in the air. An uncombined element is often called free. The atmosphere contains other free elements. There is the nitrogen so necessary for making the compounds found in protoplasm. Neon, the gas which gives the red color to lights used in advertising signs, is another element found free in the air.

The elements gold, silver, copper, platinum, iron, aluminum, lead, zinc, tin and chromium are the familiar metals. Platinum is nearly always found free in the earth's crust. Gold, silver and copper are found free and also in combination with other elements. Iron is found nearly always combined. The other metals are found only in compounds. To use them, they must be extracted from their minerals.

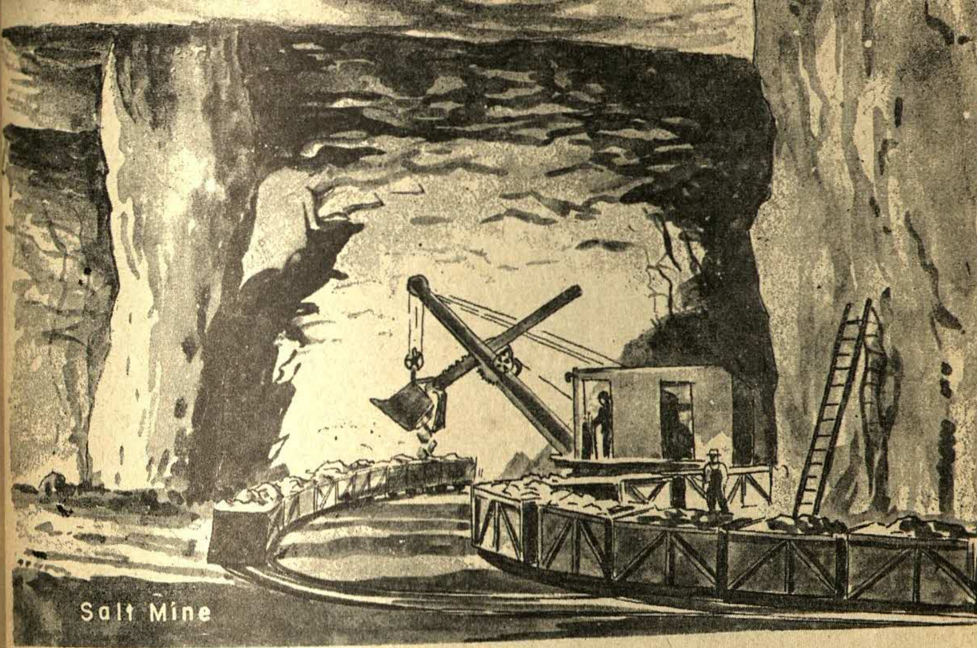
Several elements are called nonmetals. Sulphur and most of the elements found in the air are examples of nonmetals. Metals, when polished, have a shiny surface. Many of them can be hammered or rolled into thin sheets or made into wire. Nonmetals are more often brittle. They do not have the peculiar shininess that metals possess.

How are mineral deposits formed?

Changes have been going on in the earth for millions of years. Substances originally scattered through the rocks have been gathered together in time, forming the deposits of minerals. Mineral deposits are of great importance to us, for we get from them all our metals as well as salt, sulphur and many other things. It is not usual to find a deposit which is entirely one mineral. Usually there are several minerals mixed together. Such mixtures which contain one or more metals in large enough amounts to make it profitable to mine them are called ores.

Scattered minerals have been gathered into useful deposits in many different ways. Water is one of the most important mineral gatherers. Water will dissolve many substances. Deep in the earth, where the temperature is high and the pressure is great, water can dissolve substances which it does not easily dissolve at the earth's surface. When water loses its dissolved minerals in a certain place, an ore deposit is built up.

A mineral deposit can be formed by the evaporation of water that has in it dissolved materials. Salt deposits are probably formed in this way. As rain water trickles over and through the earth, it dissolves tiny amounts of salt and carries it to the ocean. The salt is left behind as the water evaporates. Year by year the ocean becomes more salty. It seems likely that in past ages portions of the ocean became cut off and the water



Salt Mine

evaporated, leaving solid layers of salt where once there was sea bottom. When buried by sediments, these formed the great underground deposits of salt which are found in several countries today. Probably some iron ore deposits were formed in much the same way. Most rocks and soils contain minerals with iron in them. Water gradually dissolves these and washes them into swamps, where they are left.

Sometimes minerals dissolved in water are deposited, or precipitated, when the solution comes in contact with some other material. We can do an experiment to illustrate this. Dissolve some copper sulphate in water. Place a piece of iron, which has been polished clean with steel wool, in this blue solution for a few minutes. When you remove the iron you will find it coated with copper. The copper was precipitated from the solution of copper sulphate by contact with the iron. In the earth, mineral deposits are often found in cracks of the rocks. As solutions seeped through the cracks, the minerals were deposited by contact with the rocks.

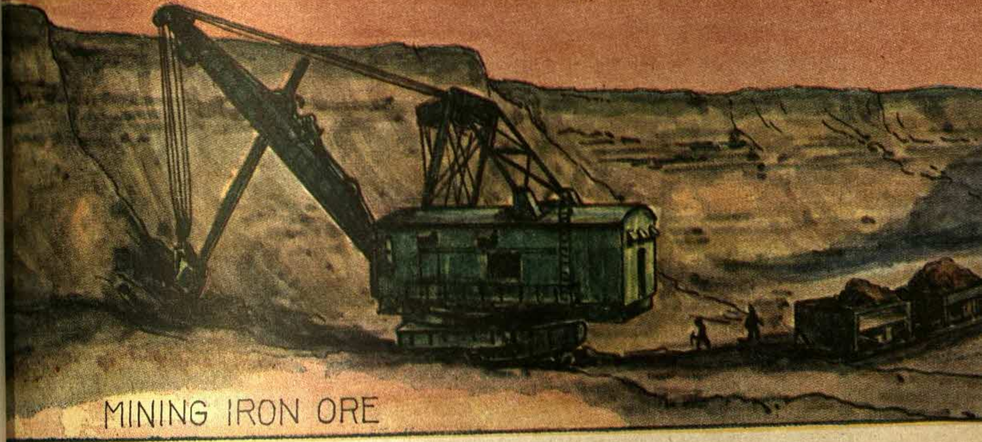
Water may carry away particles of minerals which are exposed when rocks are broken up. Gold found in the gravel of river beds was brought down from surrounding hills by running water. Since gold is very heavy, it was left behind while the lighter minerals were washed away. Some deposits of tin ore have been produced in the same way.

There are many other causes for the formation of deposits of minerals. Whatever the process may be, it always takes place slowly over very long periods of time.

What are some important minerals?

All civilized people depend on minerals to provide them with the machines and tools to carry on their work. Iron ore is one very important material without which we could not have automobiles, trains, ships and all sorts of tools and machines. The United States is fortunate in having large amounts of iron ore. One important deposit is located near the western end of Lake Superior and another near Birmingham, Alabama.

All our machines would be useless if we did not have power to run them. We get this power from burning fuel and from electricity. Coal, petroleum and natural gas are the most important fuels. All are obtained from the earth. In order to use electricity, millions of miles



of copper wire are necessary. The copper is obtained from the earth. Large amounts of copper ore are found in Montana, Utah and Arizona. However, we do not produce all the copper we need. We import a great deal of it from Chile in South America.

Aluminum is an important metal. Minerals containing aluminum are found in clay, which occurs almost everywhere. It is too expensive at present to get aluminum from clay. Other less common ores are used. Some aluminum ore is produced in Arkansas, but much more is obtained from Dutch Guiana in South America.

Limestone is a rocky substance often found in very large masses. It is used as a building stone and to make lime and cement.

Salt and sulphur are necessary minerals which have many uses. We use salt for flavoring and preserving food. From it chemists make the chlorine for purifying water, the baking soda used in cooking and the lye for making soap. Sulphur is used in making sulphuric acid, which is familiar to most of us as the liquid in storage batteries. Sulphur is also used in preparing rubber for tires and in making sprays to protect plants.

There are a number of ores which we do not have in the United States. We must get our supplies of tin from the Malay States or from Bolivia. Canada has the largest deposits of nickel ores. Spain produces a large part of the mercury for the world. We need large amounts of manganese in making steel. We get most of it from other countries. We do not have enough chromium for the bright plating on automobiles, nor enough tungsten for the filaments in electric lamps, nor enough antimony for the type to print books.

Why must our minerals be conserved?

No doubt the agents which formed mineral deposits in the past are also at work today. However, they work so slowly that new deposits of minerals are not being formed as rapidly as they are being used up. There are many places where mines have been abandoned because the deposit of minerals has been exhausted. If we are to have all the minerals that we need in the future, it is necessary that we use them wisely today. There are many ways that minerals and other materials can be conserved. They are often wasted. This is particularly true of fuels. We do not burn them completely, or we do not burn them in properly adjusted furnaces or engines. Metals are used wastefully, too. When tools and machines become worn, they are often thrown on dumps and allowed to rust away. Even when a tool or machine becomes useless, the metal in it can be made into new devices. We should save scrap metal so that it can be used again. This will make it unnecessary to dig such great quantities of minerals yearly.

Some people use machinery carelessly. They allow it to rust, or it is broken by improper use so that it must be replaced sooner than it should be. This uses up minerals more rapidly than necessary.

We shall probably learn to use products made from plants in place of some metals. Plants grow more quickly than mineral deposits are formed. Plastics are examples of materials which can replace metals for some uses.

Things to Do

1. Make a collection of the common rocks of your vicinity. Identify and label them.
2. Visit a local museum and study the collections of minerals and rocks found there.
3. Obtain an argon glow lamp. Minerals which fluoresce will glow with beautiful colors when held near a lighted argon lamp in a darkened room. Test rocks and minerals to discover whether they fluoresce.
4. Prepare a report on fluorescent lights. Find what advantages and disadvantages they have in comparison with incandescent lights.
5. On an outline map of your state, mark the places where rocks and minerals are mined. Label each place with the names of minerals obtained there.
6. Invite your county agricultural agent to give a talk at an assembly on the kinds of soil in your vicinity.
7. Study the area near your city to see whether erosion is being allowed to take place. Take snapshots of damage by erosion.
8. Make a collection of the kinds of soil in your vicinity.
9. Make a report on the great deltas of the world.

10. Visit a museum and study the collection of fossils.
11. Make a collection of fossils found in your state.
12. Find out how scientists, in studying earthquakes, use the instrument called a seismograph.
13. Prepare a report about famous glaciers.
14. Make a class collection of minerals which have crystalline shapes.
15. Make a large chart showing the operation of great furnaces in which Portland cement is made.

How Much Do I Remember?

Please do not write in the book.

I. 1. .... 2. .... 3. .... 4. .... 5. .... 6. ....

(a) If rocks are broken by heating and cooling, write E in space 1. If rocks are tough and elastic, write A.

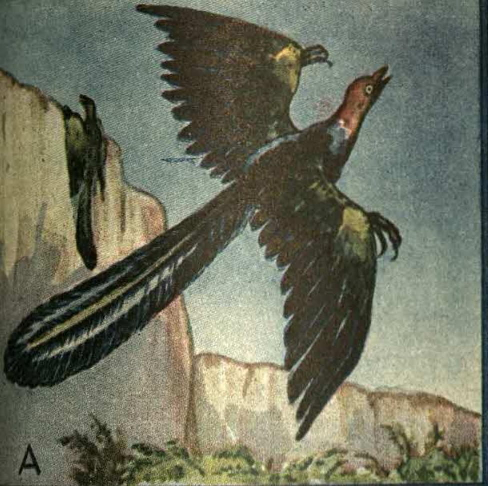
(b) If most objects contract when heated, write M in space 2. If changes in temperature are greater at sea level than in high mountains, write O. If water expands when freezing, write A.

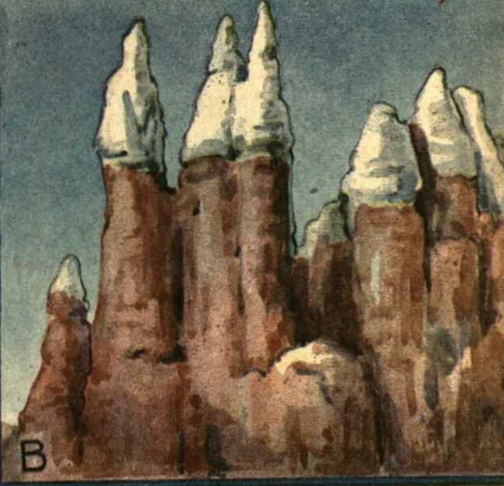
(c) If no minerals dissolve in water, write B in space 3. If water moves rocks and soil, write R. If rapid-flowing water carries less sediment than slow-flowing water, write U.

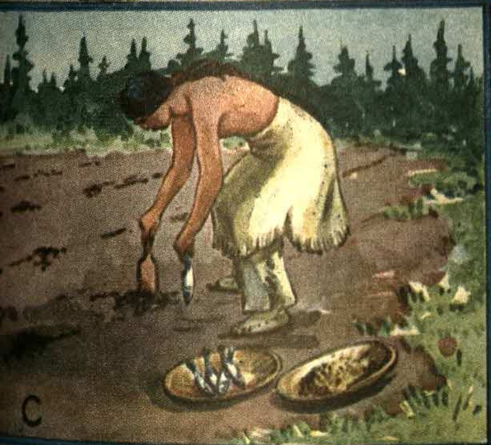
(d) If glaciers are important agents in changing the earth's surface, write T in space 4. If glaciers are more numerous now than they have ever been, write C. If caves are formed by glaciers, write A.

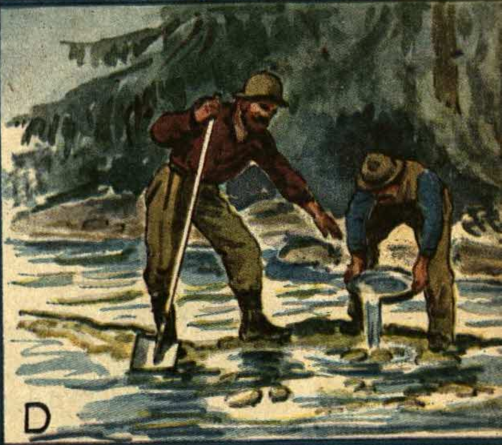
(e) If water is the most important agent in causing changes in desert regions, write S in space 5. If the roots of plants can split rocks open, write H. If otherwise, write X.

(f) If scientists believe the earth's interior is made of gold, write J in space 6. If crystals have curved surfaces write O. If igneous rocks contain crystals, write S.









A. What is the name of this fossil bird? How does it differ from modern birds? About how big was this bird? In what ways did this bird resemble a reptile?

B. What processes could have made these formations? What class of rocks is shown here?

C. Why did the Indians put fish in the hills of corn? How does the modern farmer achieve the same purpose?

D. For what are these men searching? How have their methods been improved?

II. Select the best word of the choices given to complete each statement.

1. The wearing down of the earth's surface by running water and wind is called (a) corrosion, (b) stratification, (c) solution, (d) erosion.
2. The sudden movements of parts of the earth's crust are called (a) eruptions, (b) earthquakes, (c) metamorphoses, (d) explosions.
3. Melted rocks thrown out of volcanoes are called (a) lava, (b) sediment, (c) clay, (d) granite.
4. Heat and pressure may cause (a) sedimentary, (b) igneous, (c) metamorphic, (d) black rocks to form from other rocks.
5. (a) Slate, (b) marble, (c) obsidian, (d) limestone is a common sedimentary rock.
6. When clay mud is changed into rock, it becomes (a) basalt, (b) conglomerate, (c) shale, (d) coquina.
7. The remains of animals and plants are sometimes found in rocks as (a) fossils, (b) crystals, (c) lenticels, (d) spores.
8. Scientists believe that the age of the earth is probably about (a) 50,000 years, (b) 750,000 years, (c) 5,000,000 years, (d) 2,000,000,000 years.
9. Dinosaurs were common during the Age of (a) Coal, (b) Reptiles, (c) Fishes, (d) Modern Life.
10. (a) Peat, (b) mica, (c) clay, (d) humus is decayed plant and animal material which is mixed with mineral matter in the upper layers of soil.
11. Changes in the rocks and minerals that help to make soil are called (a) crystallization, (b) weathering, (c) erosion, (d) percolation.
12. A material found in the earth which contains a metal that can be mined profitably is called (a) mineral, (b) ore, (c) quartz, (d) stratum.

THE CONTINUITY OF LIFE

INSTITUTE OF EDUCATION FOR WOMEN
Dept. of Extension
SERVICE.
CALCUTTA-27

The Many Kinds of Living Things

Written records show that when the early settlers came to this country they looked for a number of things before settling in a region. Especially, they wanted land that would grow crops readily, and plants and animals that could be used as food. Possibly, none of the foods you have eaten today and none of the clothing you are wearing, are from plants or animals like those living in North America when the Plymouth settlement was founded in 1620. Then there were no cows, no pigs, no sheep and no hens on this continent. There were no oranges, apples, cabbage, carrots or peas. Is it any wonder that so many settlers died of scurvy during the first winter? The men who founded the Plymouth colony were neither fishermen nor hunters. They had landed in the winter. Unbroken forest stretched west, south and north, except for little clearings where the Indians grew patches of corn and beans. The food supply was both uncertain and unbalanced.

What a difference the country presents today after three hundred years of development! Some native American plants and animals still supply us with food today. However, most of the plants which we see on every hand in gardens, fields and orchards, have been brought from other countries and have adapted themselves to life in changed surroundings. Many were brought as precious seeds or cuttings on ships bearing the colonists and their belongings. They were carried by families in covered wagons from east to west. The native animals and plants have been replaced by others more suited to our needs.

How are living things distributed on the earth?

Living things are found practically everywhere on the earth: in salt water, in fresh water, on land, and as parasites in or on the bodies of other plants and animals.

Ordinarily salt-water animals cannot live in fresh water or on land. Some live near rocky, sandy or muddy beaches, some in the open ocean and some on the ocean bottom. Algae are the most numerous forms of plant life in the ocean. Many are very large in comparison with the algae of fresh water. Animals in the ocean range from the simplest kinds to the most complex—from the one-celled protozoan to the many-celled vertebrate, such as the shark and the whale. The spiny-skinned starfish lives there and also most of the sponges and the corals. The shells of hundreds of different kinds of mollusks litter the sandy beaches today just as they did millions of years ago. Many of the backboneless animals which inhabited these shells are like those we have studied in the record of the rocks.

Other marine animals live on the sea bottoms, feeding on the dead bodies of plants and animals that fall to the bottom. Different living things live at different levels in the water, depending upon how much light they need. The deeper the level, the less light can penetrate the water.

Fresh-water animals and plants live in the bogs, swamps, lakes, ponds, pools, rivers and streams. Some of them like flowing water, others prefer stagnant water. The kinds of life vary with the speed of the stream, the depth of the water and the kind of bottom. Brook trout live only in clear, cold running water. They feed on insects at the water surface and on underwater forms of life. Bullheads lie on the muddy bottom of ponds and sluggish streams, feeding on worms and insect larvae. It is fun to dip into a pond and see the variety of

animals which come up in the net. There are many invertebrates in fresh water: mussels, worms, crayfish and insects. Living with them are also such vertebrates as fishes, amphibia, reptiles and even some mammals; for example, muskrats and beavers. In the water are also bacteria and algae, and sometimes the plants useful in aquaria, cabomba and elodea. Water lilies and duckweed float on the surface, while cattails and sweet flag grow partly submerged along the water's edge.

Most of us are more familiar with the living things on land. Animals like the woodchuck and the prairie dog burrow beneath the surface. Some, like certain insects, birds and mammals, make their homes in trees. Many insects, birds and bats fly a good deal, but their homes are on land or water. The kind of surroundings of a place determines the particular kind of animals to be found there. The common mole tunnels in the soil of pastures and lawns. The star-nosed mole is found in swampy land. Red squirrels are seen in coniferous woods. Gray squirrels live in deciduous woods. Chipmunks prefer homes in stone walls or brush piles, or to burrow in the ground for a place to live. Some insects live in galls which form on leaves and stems of plants.

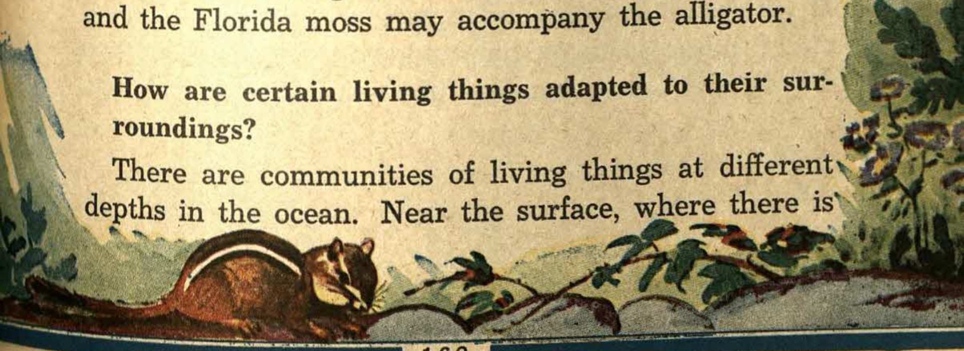
The liverworts, mosses and ferns are found in moist places on land, many under the shade of trees in the woods. Flowering plants have adapted themselves to life under varied conditions. We find them growing almost everywhere, either alone or along with other plants.

Parasites live on many kinds of living things. Some of them are not harmful to their host, while others may kill it. Bacteria, rusts, smuts, blights and molds frequently exist as plant parasites. Many kinds of protozoa, worms, insects, mites and ticks are animal parasites. No less than twenty-six kinds of protozoa can live as parasites in the body of man.

From experience and from reading we have learned to relate certain animals and plants to the places where they live. We place the penguin in the Antarctic, the walrus and the polar bear in the Arctic, the alligator in warm waters of the South, the horned toad in the arid lands of the Southwest. The cactus may be a part of the surroundings of the horned toad; the cypress and the Florida moss may accompany the alligator.

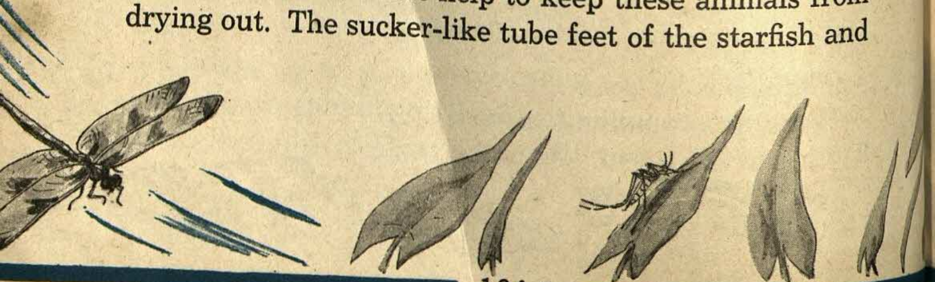
How are certain living things adapted to their surroundings?

There are communities of living things at different depths in the ocean. Near the surface, where there is



plenty of sunlight, are different algae and the many fishes which feed on them. Algae may be present to a depth of 300 feet. Below 5000 feet no light is available, so few plants can grow there. The animals far below the surface and those that live on the bottom feed on animal and plant bodies which die and sink to the bottom. Many of the fish that live at great depths are luminescent. Their bodies are slender and dark in color. Their mouths are unusually large and they sometimes lack eyes. Crustaceans, many of which live on the bottom, have long legs for walking on the soft mud. Sponges and some other animals have stalks which lift their feeding organs above the ooze. The number of living things decreases with the depth of the water. At great depths, animals are unharmed because the water pressure inside and outside their bodies is the same.

Along the ocean shore, where the tide rises and falls, and in tide pools made by rocks, we may find plants and animals that have adapted themselves to the daily changes in their surroundings. All of them are subject to the pounding of the waves and to exposure to the warm summer air and the cold winter air for hours at a time. The rockweed is adapted to living in water by holdfasts that cling to rocks. Its leathery, ribbonlike body serves to lessen the friction due to the waves. The shells of barnacles and mussels and the tough covering of the sea anemone help to keep these animals from drying out. The sucker-like tube feet of the starfish and



the sea urchin help them to attach themselves to rocks.

Clams, crabs and worms avoid the waves by living in crevices or burrows. A crab can scuttle into a burrow quickly. A sand dollar also burrows, but it cannot move so rapidly. At times it is partly exposed, but its round, flat body is not much affected by the waves.

Wherever an animal or plant is found growing naturally, it is adapted to its surroundings. The mole has shovel-like claws for burrowing. The dragonfly has a strong, rigid body with very large wings for flight. With its enormous eyes it can probably see better than any other animal around it. Thus it can catch mosquitoes and other insects on the wing.

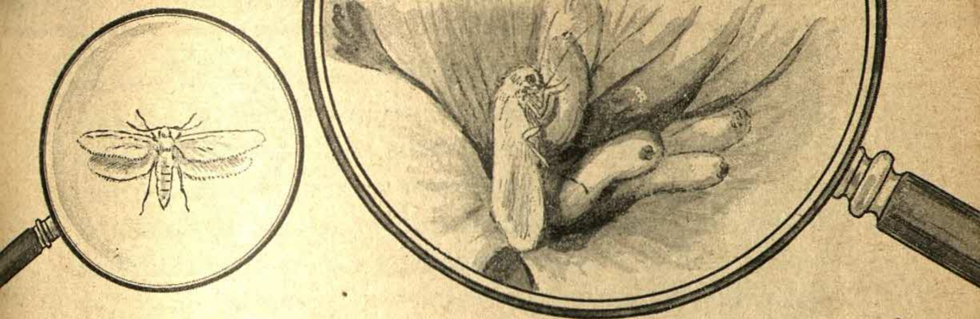
Birds are adapted for flying by having light bones and forelimbs that are wings. A system of air sacs also lightens the body of a bird. Certain of the bones are joined tightly together so as to make the back rigid. They can see things both far and near. Birds which feed on the wing, such as the chimney swift, have large mouths with bristles which help in catching insects.

How are certain living things adapted to each other?

Everywhere, and in many different surroundings, living things depend upon each other for getting what they need for life. On bark of trees, on exposed rocks, on roofs, fences and on soil we find the simple plants known as lichens. These consist of two plants living together. Threads of fungus ensnare cells of algae and the two plants together form what is called a lichen. Each is useful to the other. The fungus provides moisture; the algae make food.

Certain bacteria grow on the roots of legumes. You can see the wart-like nodules in which they live if you dig up a bean or a clover plant. Legumes must have plenty of nitrogen to make the large amount of protein found in their seeds. The bacteria get their food from the legumes, but they also take nitrogen from the soil and give it to the legumes in usable form. Man takes advantage of this partnership by raising legumes as an important food crop and as a soil fertilizer.

The pollination of plants also shows how plants and animals are dependent upon each other. Some plants are pollinated by particular insects. A striking example of this is the yucca plant, which cannot live without a



YUCCA MOTH

special kind of moth. The moth visits a yucca flower and scrapes off some pollen, using specialized mouth parts. She then drills a hole through a yucca ovary with an egg-laying device and lays her eggs among the yucca ovules. Then she carries the pollen up to the pistil and applies it carefully, so that pollination occurs. When the young of the moth hatch, they feed on seeds of the yucca plant. There are so many seeds that the plant can easily spare some to the moth. The results of this cooperation are new life for the plant and new life for the moth.

Termites are a kind of insect which destroys wood by using it as food. They can be very destructive to buildings. In their intestines are certain tiny protozoa that can digest the woody material and make it available to the termites for food.

Certain crabs place sponges on their shells. By carrying the sponge wherever it goes, the crab increases its opportunities for finding food. The crab is concealed from view by the body of the sponge. If an enemy discovers the crab, it does not attack because the sponge smells so bad and its skeleton seems to be undesirable for food.

Some hermit crabs which live in empty snail shells place either sea anemones or animals called hedgehog hydroids on top of their shells. These animals have stinging cells which drive away intruders that might bother the crab. Some of the droppings from the mouth of the crab are used for food by the animal riding on its shell.

Wherever ants are found on a plant, plant lice will probably be found there also. The ants protect these lice, called aphids, by collecting their eggs in autumn. They care for the eggs in underground nests until spring; then they carry the young aphids to the roots of plants which they infest. In return, the ants receive drops of "honeydew" given off by the aphids.

These are but a few examples of ways in which living things adapt themselves to each other. As our acquaintance with plants and animals grows, we are constantly discovering new cases of interdependence.

How has man adapted himself to different surroundings?

Man is a part of his surroundings and is never free from their effects. He, too, must be adapted to his environment in order to live successfully.

Two of the early adaptations of man's body were the thumbs, which enabled him to grasp objects, and a type of feet and legs that gave him the ability to stand erect. Thus, he could use the forelimbs for handling objects rather than for walking. This increased his physical power. The walls of caves in which early man lived show drawings and contain objects which prove that he was not only a hunter and a warrior, but also a painter and a sculptor. He learned to use fire and to cook food. He tanned skins, discovered how to weave rushes into baskets and plant fibers into clothing. He made dugouts and canoes for getting about on water. Beginning life in caves, he later learned how to build magnificent dwellings. The ancient Peruvians, for example, built homes of perfectly shaped stones, neatly fitted together without the aid of mortar.

Early man was a traveller. He was often forced to wander from place to place in order to find a steady supply of food. If he wished to stay in one region, it was necessary for him to preserve the balance of nature or he could not survive. The American Indian understood this. When the first white settlers came to North America, they found the Indian living in a state of balance with nature, taking only what was necessary

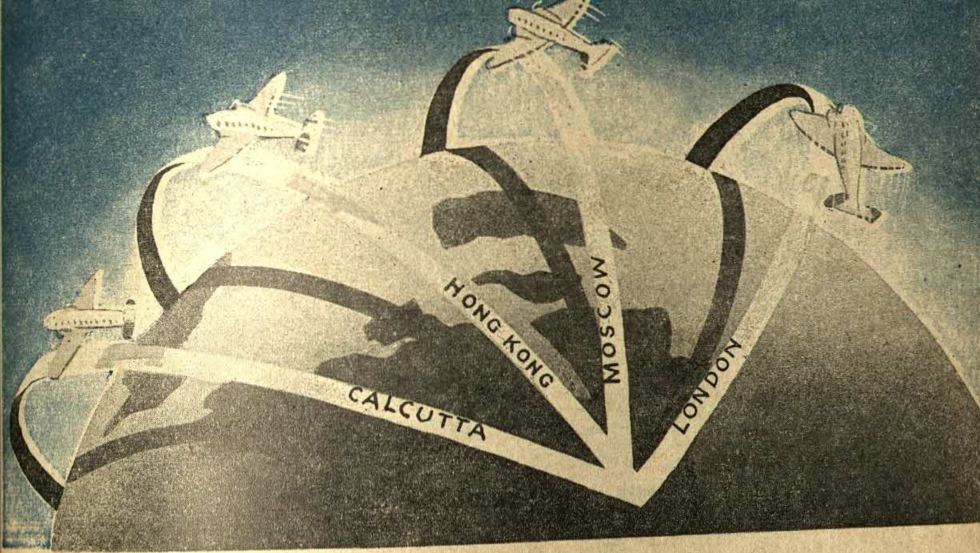
ANCIENT AND MODERN AGRICULTURE

for life and allowing living things to reproduce themselves. The forests, the game and the soil of North America were then in a state of natural balance.

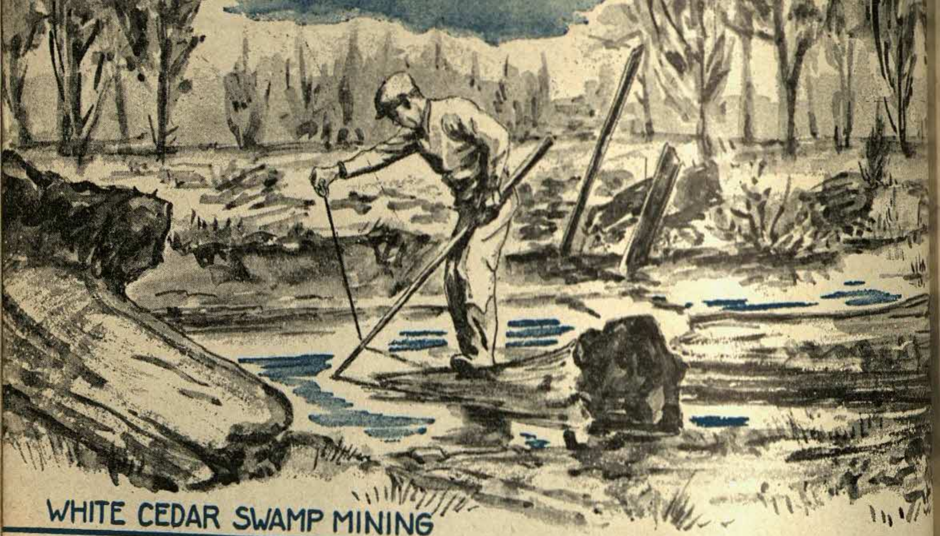
Another adaptation took place when man learned to domesticate plants and animals. Horses and cattle were herded and driven by man to places where fresh forage could be found. Later he learned to grow grains and other plants to provide food for them and for himself. The dog was among the first animals to be domesticated. He was useful to man and man was useful to him.

With the domestication of animals and plants, civilization developed wherever the soil and growing conditions were favorable for the production of a supply of food. Population increased rapidly and the number of communities grew. When labor was plentiful, large projects such as the Pyramids were sometimes undertaken. The Pyramids remain to this day.

As surroundings continued to change, new adaptations developed. Out of man's curiosity about the heavens came the science of astronomy. This helped him to navigate the seas and to establish the time calendar. As the use of metals was discovered, stone implements were replaced by implements of copper, bronze, iron and steel. With better tools more food could be grown. Ships were used to export products from one place to another. The building of ships led to exploration. Other continents were colonized, and communication was set up between them. Today, only a few minutes are needed to connect a line of communication between almost any two spots on the earth. No place on earth is more than a few days away by airplane from any other place.



Most of what man does today to adapt himself to living is like the activities of primitive man, but on a larger scale. His basic needs are the same, but science has made human progress more orderly and less subject to trial and error. The study of man's history shows that he protects himself by improving certain living things and destroying others. Also, he has learned to live with other living things, although he has not yet been too successful in getting along with other peoples. He has only partly solved the problem of killing disease germs and certain insect life. Early man used his natural environment without disturbing it greatly Modern man has often upset the natural balance to gain his own ends. Knowing the consequences, he must now proceed cautiously, since his own survival may depend upon a wise use of the things in his surroundings.


WHITE CEDAR SWAMP MINING

The Need for New Living Things

The giant sequoia trees of California are among the biggest and oldest trees on earth. Some of them tower 300 feet in the air. The oldest are said to be about 4000 years old. In the eastern part of our country there are no trees which have the life span of the sequoia, but some of them have lived to be very old and have a most interesting history.

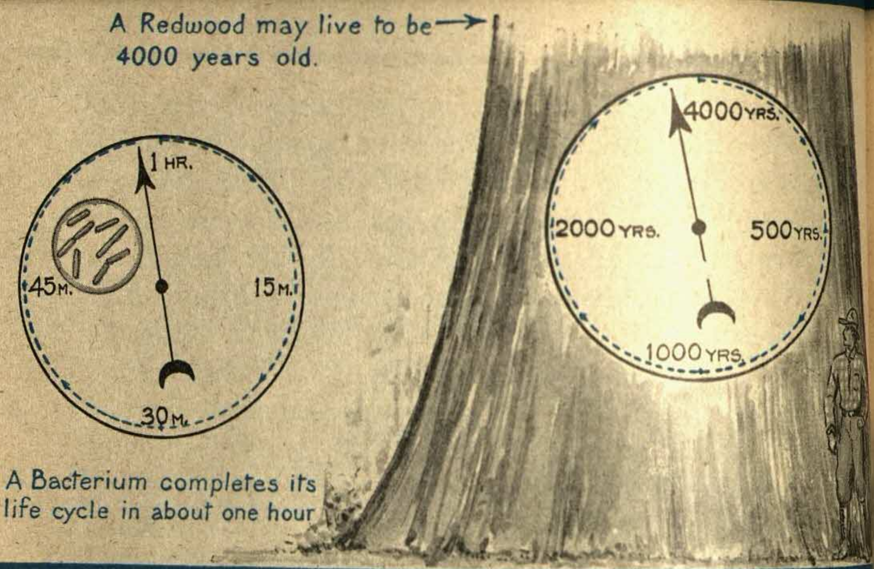
In southern New Jersey, one can find the white cedar, an evergreen tree which grows in fresh-water swamps. Several thousand years ago, these trees grew to great size—up to six feet in diameter. Many such giants, not well rooted in the swamp, toppled over during severe windstorms. Because of their weight, they sank into the soft muck of the swamp. Silt from streams helped cover them. New trees grew up where the old ones had been. The early settlers of New Jersey found a dense growth of white cedar in the swamps, but lying buried underneath were a host of dead trees. They had been there for several thousand years, sealed from the air by water, perfectly preserved, and piled like jackstraws.

Since 1800, whenever labor has been available, these trees have been "mined." Getting the giants out of the muck of the swamp is a real task. The wood is useful, once obtained. The best logs are used for industrial water tanks and boat decking, the smaller ones for shingles and for other purposes, such as greenhouse benches. In 1913 Independence Hall in Philadelphia was reshingled with materials from these old mined cedars of New Jersey. A study of the trunks of these trees shows that the best and the largest of them were 500 years old when they toppled into the swamp.

What is the life span of different plants and animals?

In higher organisms, the time between birth and death is called the *life span*. In lower organisms such as a bacterium, a *life cycle* may be completed in an hour; but the bacterium lives on in its daughter cells. A salmon reproduces once, then dies. Its life span and life cycle are the same. This is also true of an annual plant such as corn. In other types of plants and animals, life cycle is shorter than life span. A giant sequoia may produce seed and so finish a life cycle in 150 years; but the tree may live for 4000 years.

Higher plants can be grouped into three classes according to their life spans: annuals, biennials and perennials. Annual plants come from seed, grow to full size,



A Redwood may live to be 4000 years old.

A Bacterium completes its life cycle in about one hour

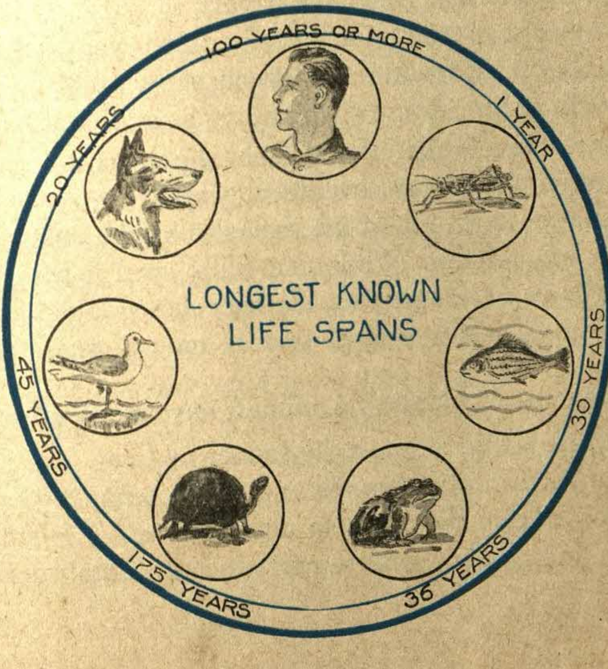
1 HR.
15 M.
30 M.
45 M.
4000 YRS.
500 YRS.
1000 YRS.
2000 YRS.

produce blossoms and seed, then die within a year. Corn and beans are examples of annuals.

Biennials are plants which live for two growing seasons, producing seeds at the end of the second season after which the parent plants die. The cultivated carrot and the wild carrot are biennials. During the first season the carrot stores food in the fleshy root which people use for food. If left in the ground, the plant would use this stored food to help produce seeds during the second and last season of growth.

Perennials live on for more than two years, producing seeds when the plants mature. An apple tree produces fruit when it is from five to nine years of age, depending on the variety. Every kind of tree reaches maturity within a certain length of time. After that, it goes through a period of old age. Its vigor decreases, its resistance to fungus diseases and insect attacks is lowered, and eventually it dies. In planning plantings around homes and public places, one needs to know how fast-growing a shrub or a tree will be, how great its spread of branches in maturity, its resistance to disease and its life span. Some poplars and birches, for example, are rather short-lived, dying in about thirty years. Oaks have a life span of a hundred or more years.

We know more about the life span of domestic animals than of wild animals. A dog that lives to be twenty has reached old age. Most dogs die at fourteen to fifteen years. Although cats have been known to live for more than twenty years, sixteen to eighteen years is their average life span. In rare cases, horses have been known to reach forty years of age, but they seldom live to be



more than thirty. Cattle may live to be somewhat over thirty, sheep over twenty. However, a cow is not considered useful for producing milk much beyond the age of ten or twelve years.

Wild deer probably have a life span of ten to fifteen years. Elephants may live a hundred years or more. Birds usually live fifteen to twenty years, although cases of longer life have been noted. A herring gull is said to have lived forty-five years, a swan seventy, a goose eighty, and a parrot eighty-two. Some crocodiles and tortoises are known to have lived a hundred years or more. One toad lived thirty-six years. The story that certain toads live for hundreds of years embedded in rocks is not true.

The life span of many fishes is not accurately known. It is believed that pike live a very long time. Striped bass have been known to live for thirty years, carp for sixty, and trout for fifteen. Insects show great variation in length of life. Some of them live as adults only a few days or hours, while others, such as one kind of cicada, live underground for seventeen years.

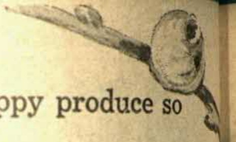
Variation in length of life seems to be the rule among plants and animals. While man's life span is something over 100 years, his present life expectancy is only about 65 years. Modern medical science may increase this.

Why must all plants and animals have many offspring?

All plants and animals die sooner or later. Any kind of plant or animal that did not have offspring would disappear from the earth in a short time. The smaller plants and animals tend to reproduce in large numbers, since their many enemies seek them out for food. Bacteria, algae and protozoa are examples of small living things that reproduce quickly and in great numbers. Many of them are eaten by crustaceans and even whales.

Fungi, such as molds and puffballs, produce millions of spores, each of which can form a new plant. Very few fall in places that are moist enough and warm enough for growth. Hence, the world is not overrun with fungi. Not all the acorns that fall from an oak produce mature oak trees. It is easy to see that conditions of light, water and space under the parent tree must limit their growth. The wind and animals carry a few acorns some distance away from the parent plant. Some of these may find proper conditions for growth. Others are eaten by animals, or destroyed by bacteria, or picked up by people.

Wherever the danger to offspring is great, their production seems also to be large. These dangers are apparently far greater in ocean water than in fresh water. Hence, ocean animals usually produce a larger number of offspring. Millions of eggs are produced by each individual oyster. The codfish lays almost ten million floating eggs which drift about in the open sea. No attention is paid by the parents to these eggs or to the young which hatch. On the other hand, trout prepare nests, choose mates, and give some care to the young. Trout produce only a few thousand eggs. You would find it interesting to set up an aquarium for a pair of guppies. The guppy is a tiny tropical fish which keeps the young within the body of the mother until they can care for themselves. As many as fifty offspring may be



produced at one time. Why does the guppy produce so few young as compared with the cod?

Some animals care for their eggs but not for their offspring. Grasshoppers and earthworms deposit their eggs in a protective egg case in the ground. Some wasps stock their nests with paralyzed insects or spiders to be used as food by the young. Other insects lay their eggs on or near the plants and animals which the young will use as food. Look on the underside of the leaves of string beans and you will usually find the eggs of the Mexican bean beetle if these insects are present in the neighborhood. The eggs of the tent caterpillar are laid in a mass around the twig of a tree. The caterpillars will feed on the tree when they emerge with the new leaves in the spring.

The Surinam male toad presses hundreds of eggs laid by the female, into cavities in her back. The common toad lays five to eight thousand eggs in beady strings in rain pools, many of which dry up before the eggs hatch. Tadpoles of toads change to adult toads very rapidly. But it has been estimated that less than one

SURINAM TOAD

per cent of the offspring of toads reach maturity. Frog eggs are usually laid in permanent bodies of water where there is no danger of evaporation. Hence, only two to three thousand eggs are laid in a mass.

Turtles hide their eggs in a hole in the ground and tamp down the ground so it will resemble the surrounding soil. Then they leave the eggs and pay no attention to the young turtles when the eggs hatch.

Birds produce relatively few offspring in a year. Those which have nests on the ground, such as quail, produce more young than those which nest in trees, where enemies are fewer. On islands or in regions where enemies are rare, sea birds make no pretense at building a nest but lay eggs on the bare rock or in hollows in the sand. Sometimes thousands of these birds build nests on a small island.

Birds like the killdeer have nests on the ground in shallow depressions. The young are ready to follow the mother as soon as they are hatched. Their color also protects them, since it is hard to see them. Hence, these birds maintain their numbers even though few offspring are produced.

Mammals have few offspring in a year. All mammals care for their young until they can feed and protect themselves. The young are also kept within the body of the mother until they are well developed. Hawks, owls, snakes and larger mammals destroy many small mammals such as field mice. By producing from four to nine young in a litter, with several litters a year, field mice can usually overcome the losses in their numbers caused by the attacks of their enemies. The field mouse is said to produce more offspring than any other mammal in the world. Moles and bats, one an underground mammal, the other the only flying mammal, have but one litter of young each year. Man usually has but one offspring at any one birth.

We can see from the facts given above that apparently the more enemies a plant or an animal has, and the more dangers, the greater is the number of offspring. Every kind of living thing seems to be able to produce enough offspring during its life span to continue its kind on the earth.

How does man depend upon the production of new living things?

New plants and animals must be produced to take the place of those that die. Man is very dependent on plants and animals. If you look at the food shelves in a large market you can see that many plants and animals were needed to provide the food. Many trees were cut down to provide the lumber for homes and furniture, for papers and books. Many plants and animals were grown to produce our clothing. Even those

HEALTHY CHESTNUT TREES

plants and animals which continue to produce over a period of years eventually become old and die.

Man tries to improve plants and animals so that more of them will be produced and grow to maturity. He selects individual plants and animals for growth that will give him better quality and greater quantity of the product he needs. Certain cows yield more milk. Certain kinds of corn have larger ears; some taste better.

Many animals and plants die of accident or disease.

DEAD CHESTNUT TREES

Thirty years ago children and squirrels competed with each other for chestnuts which fell from the many trees along country roads and in the woods. Today very few of these chestnut trees are alive. Most were killed by a fungus bark disease brought in accidentally from China. Epidemic diseases often develop which reduce the numbers of a type of animal, thus affecting other animals which depend upon it for food. Extreme weather often causes death among plants and animals. In 1882 a severe storm brought cold water into warm waters where tilefish lived. Nearly all these fish were killed.

Man has been very wasteful of many useful animals and plants. We have already learned about the disappearance of the buffalo, beaver, heath hen and passenger pigeon. Reckless killing and destruction of their natural surroundings caused them to disappear. You may still see beaver and bison because they have been restored, but no birds of the passenger pigeons or the heath hens remain to reproduce their kind. Man realized too late that living things must be used wisely.

Today man protects many animals by law. He provides state and federal areas where animals and plants may grow without being disturbed. He studies the breeding habits of animals and protects them during breeding seasons, often allowing them to reproduce in hatcheries or game preserves. Societies for the protection of wildlife have been formed. The United States Fish and Wildlife Service makes extensive studies of animals and plants in their natural environments. The Department of Agriculture provides people with scientific knowledge about raising plants and animals.

How New Plants Are Produced

There was great excitement in the Ware family in the month of August. Half an acre of land had been bought and a new home was to be built at once. The land was on the same tract where the family had been living for six years.

"It's easy to move ourselves and the dog into the new home, Dad, but what are we going to do about the plants—the asparagus bed, the rhubarb, all the roses and other plants which we brought up from Grandmother's home?"

"I've been wondering about that myself, Bill," replied his father. "If you boys will help, perhaps we can transplant them again. It will have to be done this autumn, before cold weather sets in."

"We'll help. But how do we know where to put things on the lot?"

"Let's make a plan," said Mr. Ware.

He sat down with paper and pencil and, after talking it over with the boys and their mother, decided on the following plan.

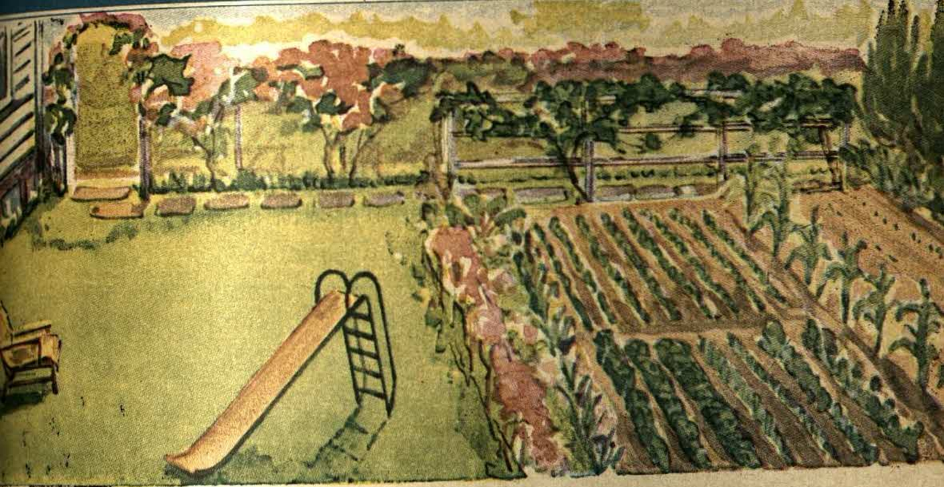
"The house will stand about forty feet from the street. Its depth," said Mr. Ware, "is about fifty feet. Your mother wants a fence across the lot about fifty feet in back of the house so that the children can play in a protected area. That leaves about a hundred feet for the garden. Now, let's see. The asparagus bed will be permanent, since asparagus is a perennial. The roots can be dug up with a lot of soil. They will make two rows across the back of the lot. Your grandfather will

bring us cuttings of Moore's Early, Isabella and Concord grapes from his vines in New England. They will make a border on our east line. We'll have to build a wooden support for them. The peony plants can be transplanted into a row in the front part of the garden. Daffodils and tulips can be replanted easily, for they are bulbs. Autumn is the proper time for this anyway, and it will do the bulbs good to be separated. The rootstocks of the iris can go here, too. The land between the asparagus and the iris can be laid out for a vegetable garden. It should be plowed and no perennials should be planted there."

"Where will the rhubarb go?"

"Better put it near a path where we can get at it easily in early spring without getting our feet muddy. The chives can go near the rhubarb. They are bulbs and a few can be separated easily from the parent clump."

During several Saturday afternoons father and sons worked hard to move the living things from the old



lot to the new. It was heavy work and they finished just in time before the ground froze.

A farmer who lived near-by delivered several loads of well-rotted cow manure to use as fertilizer. This provided nitrogenous material for the plants and it also helped loosen the soil. Rose bushes and other shrubs from Grandmother Ware's old home were bedded down in trenches of soil for the winter.

The winter passed. The family moved into their new house. There was much to do. It was August before the land was graded and the grass seed sowed for the lawns. Meanwhile, the spare land at the back had been planted in vegetables and the chain link fence erected. The plants transplanted in the fall had thrived.

"What can we plant to take off the bare look of the fence?" asked Mrs. Ware.

"How about roses? There are lots of good climbers," said her husband.

"Fine. Roses are beautiful. Don't forget to plant the old-fashioned ones, and also some of the newer varieties."

Five years passed and the garden prospered. From late in May until the middle of November, roses were found blooming on the Ware's fence. The little yellow rose from the garden of a New England friend bloomed first, followed by the American Beauty rose transplanted from Grandmother's garden. Then came a variety of new ones—blush pink, pink, white, yellow, red—followed by the old crimson rambler and the pink Dorothy Perkins.

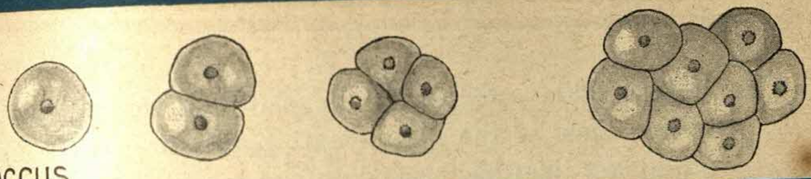
"Dad, it looks as though we had been here forever," said Bob, as he was pulling weeds from around the roses one day.

"That's what cultivation and care do for plants," replied his father. "Give them suitable surroundings and they grow and flower. They are ours in return for the care we give them."

How do simple plants reproduce their kind?

Simple plants are everywhere; in fresh and salt water, in soil, in the air, and in the bodies of animals and other plants. Many of them are single-celled. Bacteria, yeasts, molds and other forms of colorless plants and algae are all simple plants. One of the commonest kinds of green algae is the Protococcus. It grows like a green stain on the shady side of trees, fence posts and unpainted buildings. Scrape a bit of the green material from the bark of a tree and look at it under the microscope. You will see round single cells like little green balls. Some of them are clumped together; some are in groups of two cells, or four cells.

Each Protococcus plant is made up of protoplasm

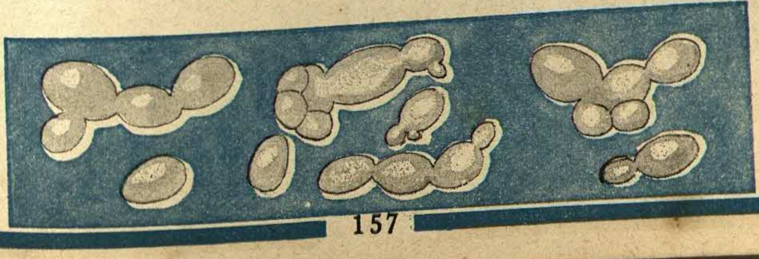


PROTOCOCCUS

surrounded by a cell wall. The cell is filled with a big chlorophyll body which makes it green. A denser part of the protoplasm is the nucleus. The plant reproduces in a simple way. Each cell divides to form two new cells. Each of the new cells formed is smaller than the parent cell. After each new cell grows and becomes mature, it divides again. The new cells may cling together for a time in groups of two or four. Sometimes a group of cells forms a colony. This process of reproduction by division is known as *fission*.

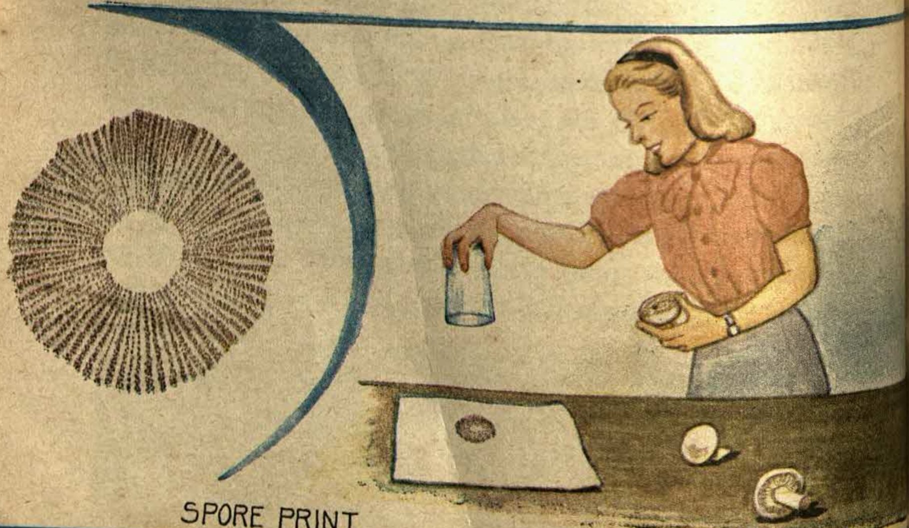
Bacteria also reproduce by division. Each cell divides into two nearly equal halves. Each half then grows into a new bacterium. If the environment is favorable, reproduction goes on very fast. Bacteria are so tiny that it is difficult to see them divide. However, if a culture plate is exposed to the air for five minutes, then closed, and kept at room temperature for several days, you will find that one or more colonies of bacteria have developed. A colony of bacteria appears wherever a bacterium fell on the plate originally.

Yeast plants reproduce by budding. This is very similar to reproduction by division. Grow some yeast by breaking a small piece of yeast cake into lukewarm water containing a little sugar. Let it stand overnight.



Make a slide and look at the plants under the microscope. Most of the bread-yeast plants are oval. They are bigger than bacteria. You can see little outgrowths or buds on some yeast cells. The buds are called daughter cells. Each bud has a cell wall around it. When it grows to full size, it too will produce another yeast plant in the same way.

Other plants, such as mushrooms, puffballs and molds, reproduce by spores. Look at the fresh spore caps of an edible mushroom. This is the part which grows above the soil and is used to reproduce the plant. Remove the stalk and lay the cap right side up on a sheet of white paper. Cover it with a glass and let it stand. You will get a spore print. Put some of the spores on a slide in a drop of water and look at them under the microscope. Each one of these spores can grow into a new plant. In pastures you often will notice the fungus plant known as a puffball. Kick it open. If the spores are ripe, a cloud of spore dust will rise into the air. The



SPORE PRINT

spores are scattered by the wind. Millions of spores can come from one puffball.

Molds also reproduce by forming spores. The black mold on bread develops round spore cases containing black spores. The cases burst and the spores are scattered about in the air. Mold spores are in the air all the time. To grow bread mold, leave a piece of moist bread exposed to the air, then cover it in a dish and let it stand in a warm, moist place.

How do plants reproduce by portions of themselves?

Many higher plants can be grown in other ways than by seeds. Mature strawberry plants send out runners which take root and make new plants. People buy these plants to start a new strawberry bed. When the stems of forsythia, blackberries, roses or grapevines are bent down and the tips buried, roots develop and new plants are then formed.

To grow potatoes a piece of potato is planted. One or two "eyes," which are really buds, must be on each piece. The potato is an underground stem. Growth depends upon the stored food in the potato until green leaves are formed.

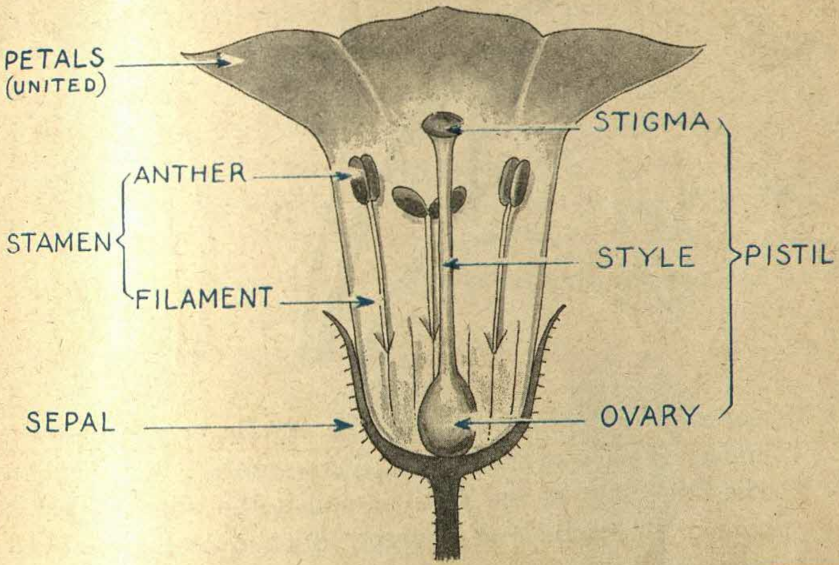
Onion sets are planted to grow onions quickly in the spring. A set is a small bulb grown from seed. A bulb is an underground stem surrounded by leaves, packed with food. Tulips, lilies and narcissuses are grown from bulbs.

Other plants have a rootstock or rhizome from which new plants arise. If a piece of the old rootstock with a bud is planted, a new plant grows. Iris is grown in this way. Some weeds have rootstocks; they are very

hard to get rid of when they take root in lawns and gardens.

New plants can be made from stem cuttings of plants such as geranium, begonia, coleus and Philodendron. Cut off a portion, several inches in length, of a new geranium stem. Place it in moist clean sand in a pot, being sure that at least one node, from which the leaf comes, is under the sand. After several weeks roots will grow. The plant can then be transplanted to a pot of garden soil. Slips of wax begonia, patience plant or coleus will take root easily in water, if a node is under the water. They can then be planted in garden soil. Certain chemical substances, called root hormones, are known to promote root growth on stems. These are now available for experimental and commercial use.

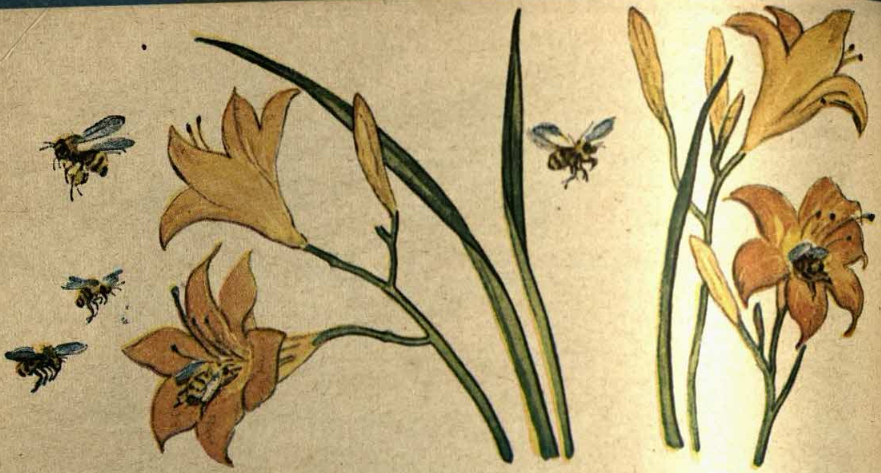
Leaves of some plants will produce new plants. Certain kinds of begonias, the African violet, sansevieria and bryophyllum are common house plants often grown



from leaves. Try growing new plants from leaves of these plants.

How do plants reproduce by developing flowers, fruits and seeds?

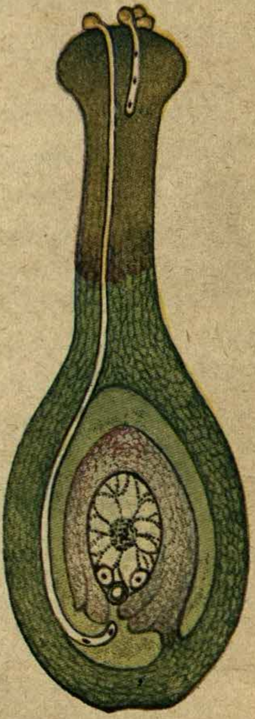
Most common garden plants are produced by seeds bought in packets or by the pound from seedsmen. Plants which produce seeds also bloom. There is great variety in the kinds of flowers and the ways in which they are produced. Let us begin our study with a large flower, such as a petunia or a lily. The typical flower has an outer circle of parts, called the sepals, which are usually green and leaflike and together form the calyx. Within the calyx is a circle of petals, often bright-colored, which



make up the corolla. Within the corolla are the most important parts of the flower. At the center is the pistil. The sticky tip of the pistil is called the stigma. The base of the pistil is the ovary, which contains one or more ovules. If you cut open the ovary of a flower, you will see the ovules. The pistil is known as the female part of the plant. Around the pistil are the stamens. At the tip of the stalk of each stamen is an anther in which pollen is produced. The pollen is known as the male part of the plant. When the pollen is ripe, it escapes from the anther as a dusty substance. Pollen must reach the stigma of a flower of the same kind before seeds can be formed. Many more pollen grains are produced than egg cells. The transfer of pollen takes place in different ways in different plants. Grasses and many trees, such as the oak and hickory, usually have very small flowers with stamens and stigmas exposed; wind blows the dry pollen to the stigma of the flower. The stigma which receives the pollen in such plants is feathery. This makes it easier to catch the pollen.

Insects carry the pollen of many plants from one flower to another. This is called cross-pollination. Bees are especially helpful to man in doing this work. The bee goes to the flower in search of nectar for making honey, and pollen for feeding young bees. The bee has special devices for carrying pollen on its legs. As it collects the nectar, pollen gets onto its hairy body. In going into another flower of the same kind, some of the pollen brushes off the bee's body onto the sticky stigma of the pistil. If the pollen from the anthers of a flower pollinates the same flower, the process is called self-pollination. Some plants have male flowers containing stamens on one plant and female flowers containing pistils on another plant, as is the case in the willow and the holly. Cross-pollination is necessary in such plants. If one wants to have a holly tree with red berries, a male tree must be planted near a female tree.

After pollination, the pollen grain begins to grow and forms a tube which grows down into the ovary. In each pollen grain are two nuclei



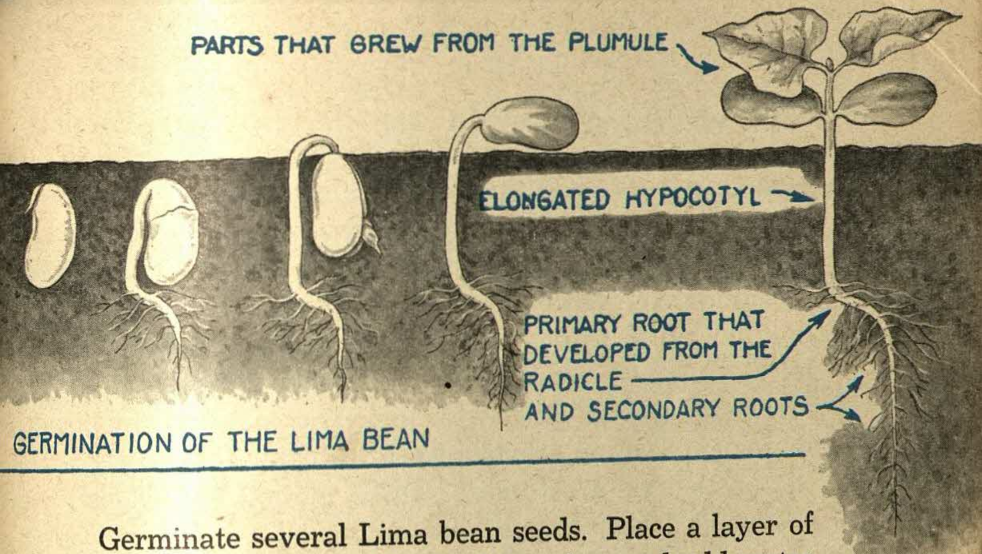
Pollen Tubes

called sperm nuclei. One of these unites with an egg cell. This union of the egg cell and the sperm nucleus is known as fertilization. After fertilization has taken place, the ovules begin to grow into seeds.

The fruit of a plant is the ripened ovary including one or more seeds and any other parts of the flower that may be closely connected with the ovary. Like apples and peaches, pumpkins, acorns and milkweed pods are fruits. A blackberry and a strawberry are fruits made up of many fruits joined together. Each seed of a fruit contains an embryo which can grow a new plant.

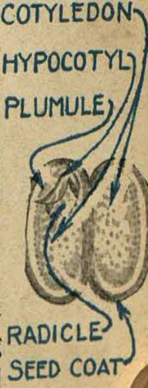
How do seeds grow into mature plants?

Have you ever seen the young plant, or embryo, in a seed? Soak some lima bean seeds overnight. The next day, notice the smooth protective seed coat and the scar where the bean was attached to the pod. Remove the seed coat carefully. The embryo of the bean has four parts: the tiny root, or radicle; the small stem, or hypocotyl; the bud, or plumule; and the seed leaves, or cotyledons. When the embryo begins to grow, the radicle grows into the primary root. The bud develops into the leafy upper part of the plant. The cotyledons provide nourishment for growth of the young plant. As soon as the plant grows green leaves, the seed leaves fall off. Cut open a grain of corn and look at the embryo. In the corn there is only one cotyledon. The food in the corn is stored in a large mass called the endosperm. Plants with two seed leaves are called dicotyledons, or dicots. Those with one seed leaf are called monocotyledons, or monocots.


PARTS THAT GREW FROM THE PLUMULE
ELONGATED HYPOCOTYL
PRIMARY ROOT THAT DEVELOPED FROM THE RADICLE
AND SECONDARY ROOTS

GERMINATION OF THE LIMA BEAN

Germinate several Lima bean seeds. Place a layer of cotton in the bottom of a drinking glass and add water to cover the cotton. Line the glass with a roll of blotting paper. Place several soaked seeds between the blotting paper and the glass. If you place them in different positions, you can see how the root and stem grow. Another way is to germinate them on a moist cloth, absorbent paper or clean sand, placed in a covered shallow tray. Seedsmen test seeds to find out how many will grow. They find the percentage of germination. Sometimes the percentage of germination is marked on the package. You can test seeds yourself by growing a definite number of seeds in a box of clean, moist sand and then counting the number which germinate.



Plant seeds of tomato, pepper, cabbage, beans and peas to find out what happens to the cotyledons when the seeds germinate.

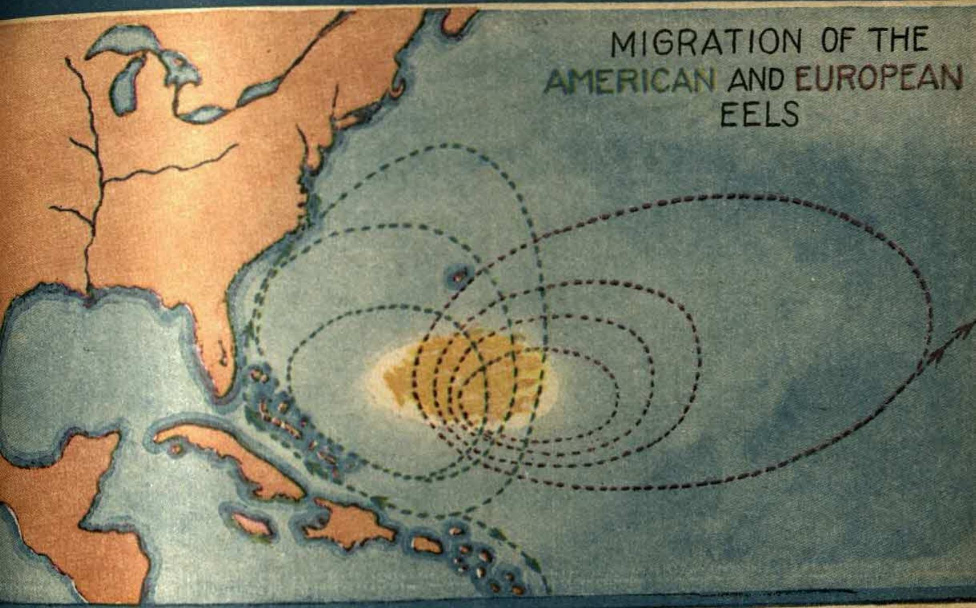
The majority of our food plants and most of our forest trees produce new plants from seeds.

How New Animals Are Produced

The eel has a very interesting life history. It is the only fish that migrates into salt water to produce its young, after living in fresh water from early youth until breeding time. The old eels never return to fresh water, but their offspring do. Eels feed and grow in fresh water for six, eight or more years. When the time to breed arrives, they gradually work their way downstream to the Atlantic Ocean, travelling southward to the Sargasso Sea north of the West Indies. There, in the warm waters, the female lays from five to ten million eggs. The parents then die.

Until 1925 the life history of the eel was a mystery because the young were so different from the parents that they were not recognized as eels. Finally some Danish scientists who were studying deep-sea life supplied the missing chapters in the life history of the eel. It was discovered that baby eels are thin, flattened, and so transparent that their bones can be counted For almost a year baby eels travel from the breeding place toward fresh water. Gradually they take on the appearance of adult eels. By the time the young eels, or elvers, come up the rivers, they are about three inches long. It is believed that they go to the same rivers and ponds from which their parents came.

The European eels leave European streams and breed in the same area to the east and north of where American eels breed. The European eel differs from the American eel in that it has more vertebrae in the backbone.



Baby European eels require three years to travel the dangerous journey to the fresh waters of Europe. There is no record showing that any eel has ever made the mistake of going to the wrong continent.

The shad is also a migratory fish. Like the salmon, it spends the greater part of its life in salt water, but ascends rivers to breed in the fresh water during the spring of the year.

Why do young eels go from salt water to fresh water? Why do eels travel to a particular region to breed? How do baby eels know which continent to head for when they leave the breeding grounds? Why do shad and salmon leave salt water and seek fresh water? We do not yet know the answers to all these questions. The best we can say is that these animals act by *instinct.* Some kind of force urges them on.

How do single-celled animals reproduce their kind?

The very simplest animals are called protozoa. Thousands of them may be present in a drop of pond water taken from places where submerged plants are decaying. The ameba and the paramecium are examples of protozoa which can be studied under a microscope.

Boil a handful of hay in a quart of water and pour off the straw-colored liquid into a quart-sized jar. When it cools, add a liberal amount of the pond water and some of the ooze scraped from plants in the water. Let this stand uncovered for two or three weeks. A scum containing bacteria will form on the surface. The bacteria feed on the nutrients in the straw-colored liquid, or hay infusion. If there are any paramecia present, they will develop on the under surface of the scum. Holding the jar up to the light, one can see very tiny objects moving about below the scum. These are the paramecia. They feed on the bacteria and on smaller protozoa in the hay infusion.

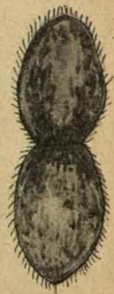
Now place a bit of the scum in a drop of water on a microscope slide. Cover it with a cover glass. Place the slide on the microscope stage for observation. You should see many protozoa, including paramecia. The latter, shaped like slippers and moving about actively, are among the largest of the organisms to be seen.

If you are lucky, you may see a paramecium dividing in two. Paramecia reproduce by fission, just as very simple plants do. If conditions are favorable, each new cell grows rapidly and reaches the size of the parent cell. Plants and animals which divide in this way may die because of starvation, but they never die of old age.

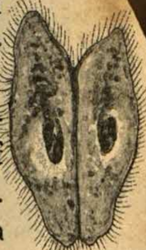
If you examine the hay culture frequently, you may see two paramecia lying side by side. They seem to be joined together. A bridge has been formed between them. Biologists have discovered that the two paramecia exchange nuclear material across the bridge. (Many other animals and plants go through a similar process, which is called *conjugation*. Conjugation seems to renew the vigor of the animal.) After the exchange, the paramecia separate. Then each paramecium splits in half by fission, after which each new paramecium continues to split in half when it grows large enough.

Some one-celled animals reproduce by spores at certain times in their life history. They set free a lot of little bodies, each of which can form a new individual. These are the parasitic protozoa, such as the malaria germ.

PARAMECIUM



DIVISION



CONJUGATION

How do some animals reproduce parts of themselves?

If you have ever had the fun of hunting pine lizards, you may have had the experience of having the lizard's tail wiggling in your hand while the rest of the creature escaped up a tree. If you were to catch this animal and keep it in a terrarium, with proper food, you would find that its tail would in time grow again. It would not be as long or as good-looking a tail, nor would it have any bones in it, but it could be called a tail. Crayfishes, crabs or lobsters may be found which have one leg smaller than the others. This leg is growing to replace the one torn off by some enemy or by accident. The ability of animals to replace lost parts is known as *regeneration.*

Some sponges form buds. A bit of protoplasm from the parent pushes outward, enlarges, and a new individual finally breaks away. Many sponges, if cut in pieces, will grow a normal animal from each piece. When injured, an earthworm can often replace the part of its body which has been torn off. A starfish can regenerate a whole body from a single arm that has a piece of the disk left on it. Before this was known, oystermen used to take starfish which they found feeding in their oyster beds, break their bodies into pieces and throw the pieces overboard into the water again. This made matters even worse than before. Most of the higher animals are not able to regenerate lost parts.

How do many-celled animals reproduce their kind?

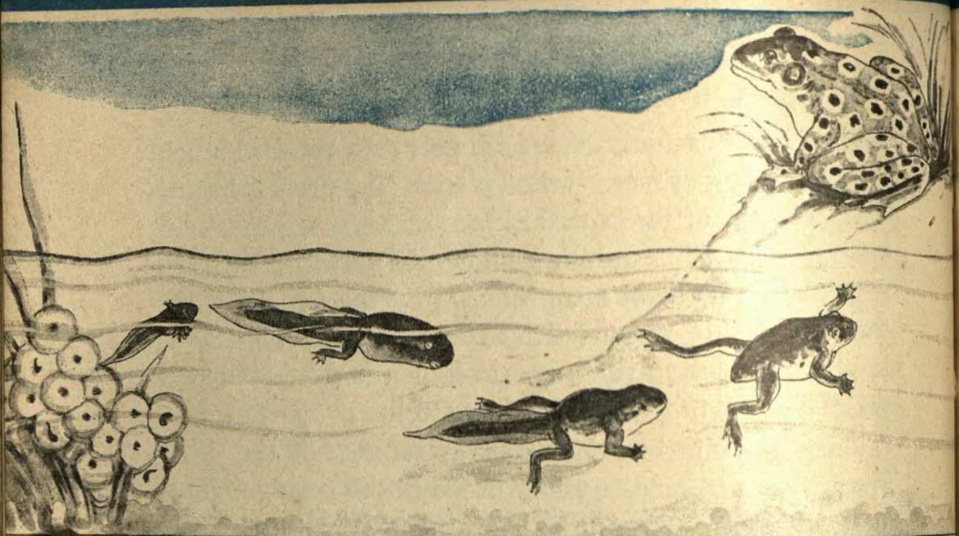
The young of many-celled animals are produced much like the young of many-celled plants. The process begins with a union of two special kinds of cells, egg cells and sperm cells. This union is known as *fertilization.* The eggs to be fertilized are produced by the female, while the sperms are produced by the male. In animals, as in plants, the number of sperm cells produced is always greater than the number of egg cells.

Most animals breed at certain seasons of the year. Frogs, fish and birds usually breed in the spring. Mammals, like the deer and the bear, breed later in the year. Fish become brighter in color and more active at breeding time. Birds have brighter plumage and sing. Male deer, muskrats, seals and other animals sometimes fight with each other over the females of their kind.

A fresh-water fish, such as the perch, deposits about one hundred thousand eggs in a ribbonlike mass in the shallow waters of lakes and ponds. The male perch swims over the mass, depositing sperm cells over the eggs. The eggs hatch in two to four weeks if conditions are favorable. Not very many eggs develop, because other fish and water birds feed on them. Some fish, such as the horned dace, make a nest in which the eggs are laid. The male guards the eggs until they hatch.

Fish hatcheries are maintained in many states to raise the young of important food fishes under controlled conditions. The young are protected during the dangerous period of their lives, then are put into streams and lakes throughout the state.

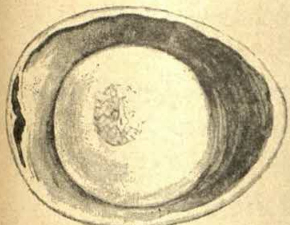
Both frogs and toads breed in water. Their eggs can



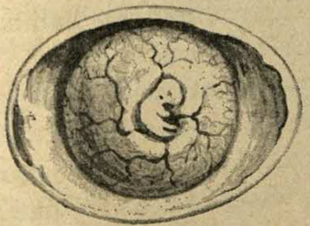
often be found attached to sticks or reeds in quiet, shallow water. Frog eggs are clumped together in jellylike masses. Toad eggs are found gathered in double beadlike strings. The jellylike material around the eggs helps to keep them from being eaten by other animals. They are fertilized by sperm cells when the female deposits them in the water. The little animals which hatch from the eggs have tails but no legs. They are called pollywogs or tadpoles. First they feed on the tiny living things in the water, breathing by means of gills. Then hind legs appear. These are followed by front legs. The tail is soon absorbed and lungs develop for breathing out of water. This series of changes is called *metamorphosis*. Different kinds of frogs require different lengths of time to go through these changes.

Some reptiles reproduce by means of eggs which hatch outside the body; others bear their young alive. Sperm cells are placed in the body of the female by the male reptile. Thus, the eggs are fertilized before they are laid. Turtles dig holes in the ground, lay their eggs, cover them and leave them to be hatched by the warmth of the sun. The common snapping turtle lays several dozen eggs at once. The alligator lays 20 to 40 eggs in a nest, where they hatch. The common garter snake produces living young, sometimes as many as 30 at one time. Young snakes receive no parental care and shift for themselves after birth or hatching.

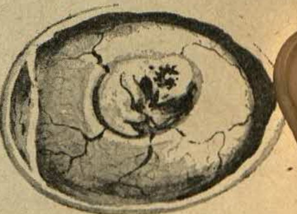
The nesting habits of birds are interesting and varied. Birds make a nest of one sort or another and deposit a certain number of eggs in the nest. The eggs are then kept warm by the female, the male or by both, until they hatch. Mourning doves lay two eggs in the nest; quail lay many. The eggs are fertilized inside the body of the mother bird before the shell is formed. The egg



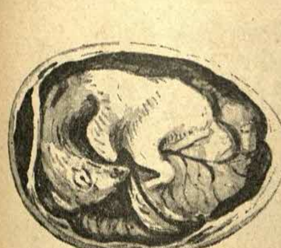
2 DAYS



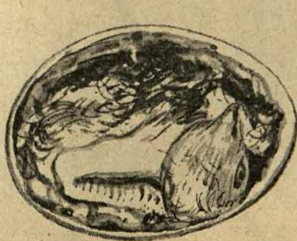
5 DAYS



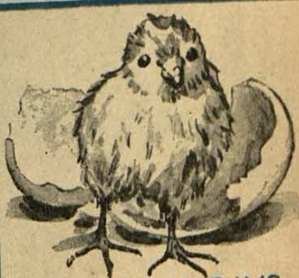
10 DAYS



15 DAYS



20 DAYS



21 DAYS

of a bird is a large egg cell. The nucleus of the egg is very small and can be found in the yolk. It is surrounded by a large amount of food in both the white and the yolk. This food is used by the developing offspring.

Among chickens, only the hen sits on the eggs in order to hatch them. The rooster does not help. Mother and father pigeons take turns on the nest, the male sitting on the eggs while the female goes off for food. A male swan also takes his turn at keeping the eggs warm. The male ostrich does most of the work of hatching the eggs.

Wild birds are so valuable to agriculture and their habits are so interesting to people that we try to provide them with places for nesting which are well protected and supplied with food and water. Man has known for a long time that birds' eggs are rich in food value. He has domesticated certain birds, such as chickens, ducks and geese. By controlling their habits, he has been able to use their eggs for food.

Scientific experiments with feeding and breeding of poultry are carried on constantly. We use the results of these experiments to produce animals better suited to our purposes. Eggs of hens are hatched in large quan-

tities in specially heated incubators. The chicks can be mothered, many at a time, in brooders heated by electricity or by other means.

Most mammals bear their young alive. The eggs are fertilized within the body of the mother. The young animal or embryo begins to grow after fertilization of the egg. In the case of the Virginia opossum the young are born after only twelve and a half days. They are almost wormlike, but by instinct they clamber up on the mother and find their way into a pouch on the underside of her body. Here each one can suck milk from the mother's body. They remain in the pouch for nearly two months.

While the developing offspring is within the body of the mother, food and oxygen in her blood vessels pass by osmosis into the blood vessels of the embryo. Obtain a pair of white rats and keep them in the schoolroom until their young are born. About three weeks are required from the time of fertilization until the birth of the young. The white rat produces a number of young in each litter.

Bring in a pair of guinea pigs and keep them in the schoolroom. A litter of young are born, about 62 days after mating takes place. This is three times as long as is required for white rats to develop. What are young guinea pigs like? Are they more dependent on the mother than are the young of the white rat?

The time between fertilization and birth of the offspring varies with different animals as follows: rabbit, 30 days, dog and cat, about 59 to 63 days; pig, about 4 months; sheep, a little over 5 months; cow, 9 months;

horse, 11 months; elephant, 20 months. About 9 months are required for the development of human offspring. Like the human being, the horse and the cow usually produce one baby at a time.

The young of mammals receive care from the mother or from both mother and father until they are able to shift for themselves. As babies, they feed on milk from the mother. All mammals produce milk as food for their young. Thus, the milk of the cow is produced to feed the newborn calf. Man takes the calf from the mother after a few days and uses the milk for himself. If fed a suitable diet and milked regularly, a cow continues to produce milk for about nine or ten months after the birth of the calf. Before another calf is born, the cow is given a rest period during which she is not milked. Experiments are being carried on constantly to find ways of improving the quality and the yield of milk by producing offspring from those cattle which yield large quantities of high-grade milk.

Things to Do

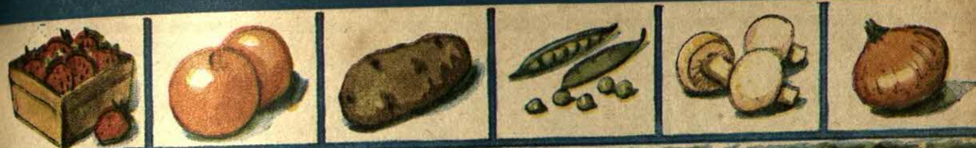
1. Make a report on the use of grafting and budding in the propagation of fruit trees.
2. Plant paper-white narcissus bulbs in pebbles in a glass dish. Plant tulips and daffodils outdoors, at home, or on the school grounds in the autumn.
3. Propagate plants of wax begonias, inch-plant, coleus, or geranium by stem cuttings.
4. Propagate rex begonia, sansevieria or African violet by leaves.
5. Propagate dahlia and sweet potato by roots.
6. Learn how to transplant house plants.
7. Propagate a pussy-willow branch in water. Transplant it into soil when roots appear.
8. If you have a suitable window space, plant such seeds indoors as can be transplanted outdoors later: tomato, lettuce, cabbages, pepper.
9. Read and report to the class about the history of the navel orange.
10. Find out how the age of trees is determined. Report on the largest and oldest trees in this country.
11. Take a field trip to a pond. Collect living things for an aquarium, such as fish, crayfishes, salamanders, tadpoles, frogs, water insects, turtles. Put them into suitable containers with some plants from the pond. Why will you have to provide separate aquaria for most of them?
12. Grow snails in an aquarium with pond plants and algae. Watch for eggs.
13. Obtain such animals as an alligator, a horned toad and a mud puppy. Learn how to arrange them in proper surroundings and how to feed them.
14. Maintain a culture of meal worms to be used as food for animals such as horned toads and other lizards.

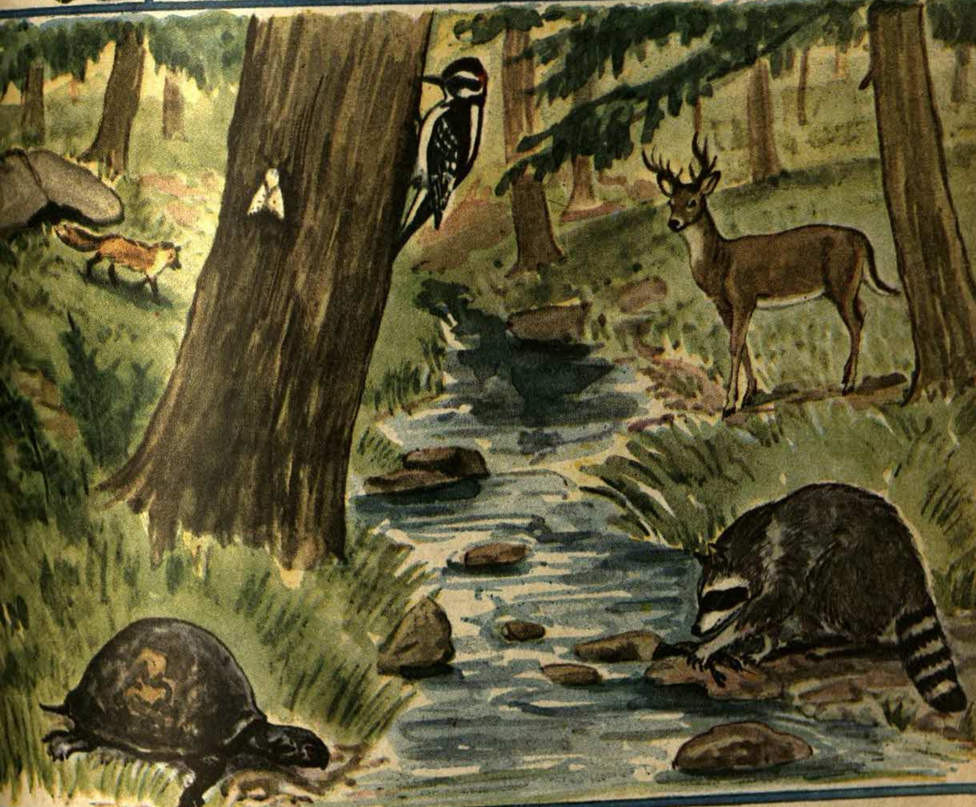
15. Prepare a box of garden soil and maintain a supply of earthworms to use as winter food for frogs, fishes, salamanders, turtles and crayfish.
16. Learn how to propagate fruit flies to be used as food for tree frogs and other small animals.
17. Bring in eggs of the toad and frog. Place them in large, shallow pans of water. Look for external gills on the tadpoles as soon as the eggs hatch. Place some of the tadpoles in an aquarium for the fish to eat. Save some in a separate aquarium with pondweed and algae and watch them grow.
18. Write a report on the nesting habits of killdeer, quail, bluebird, cowbird, bank swallow, or penguin.
19. Make a list of the mammals which live in your neighborhood. Find out about their homes, their breeding habits, and how they care for their young.
20. If your school is near a seacoast, arrange a trip to the shore to study the living things found on the beach. The kinds of life you will see will depend upon whether the beach is rocky or sandy. Watch the living things in their surroundings to see how they get about. If your school has a source of compressed air, you can set up and maintain a salt-water aquarium. Salt-water aquaria need more oxygen for maintenance than fresh-water aquaria, so that a constant supply of compressed air is necessary.

How Much Do I Remember?

I. Pick out the item in column 2 which best matches each word in column 1. *Please do not write in the book.*

Column 1	Column 2
A. opossum	1. pollen
B. blight	2. corn





1. How does each of the plants shown at the top reproduce its kind?
2. Where did each of these plants originate? How and when was it brought to this country?
3. List the important food nutrients in each of the plants shown at the top. Which are especially rich in vitamins?
4. Locate the following: crayfish, moth, box turtle, downy woodpecker, red fox, raccoon, deer.
5. What kind of home does each of these animals have?
6. In each case, how many young are born at one birth? What parental care is given?

C. ovule
D. runner
E. starfish
F. mushroom
G. stamen
H. pollination
I. monocotyledon
J. fruit

3. strawberry
4. animal
5. spores
6. oyster
7. bee
8. plant
9. plant parasite
10. pouched animal
11. pumpkin
12. pistil

II. 1. . . . . . 2. . . . . . 3. . . . . . 4. . . . . . 5. . . . . . 6. . . . . .

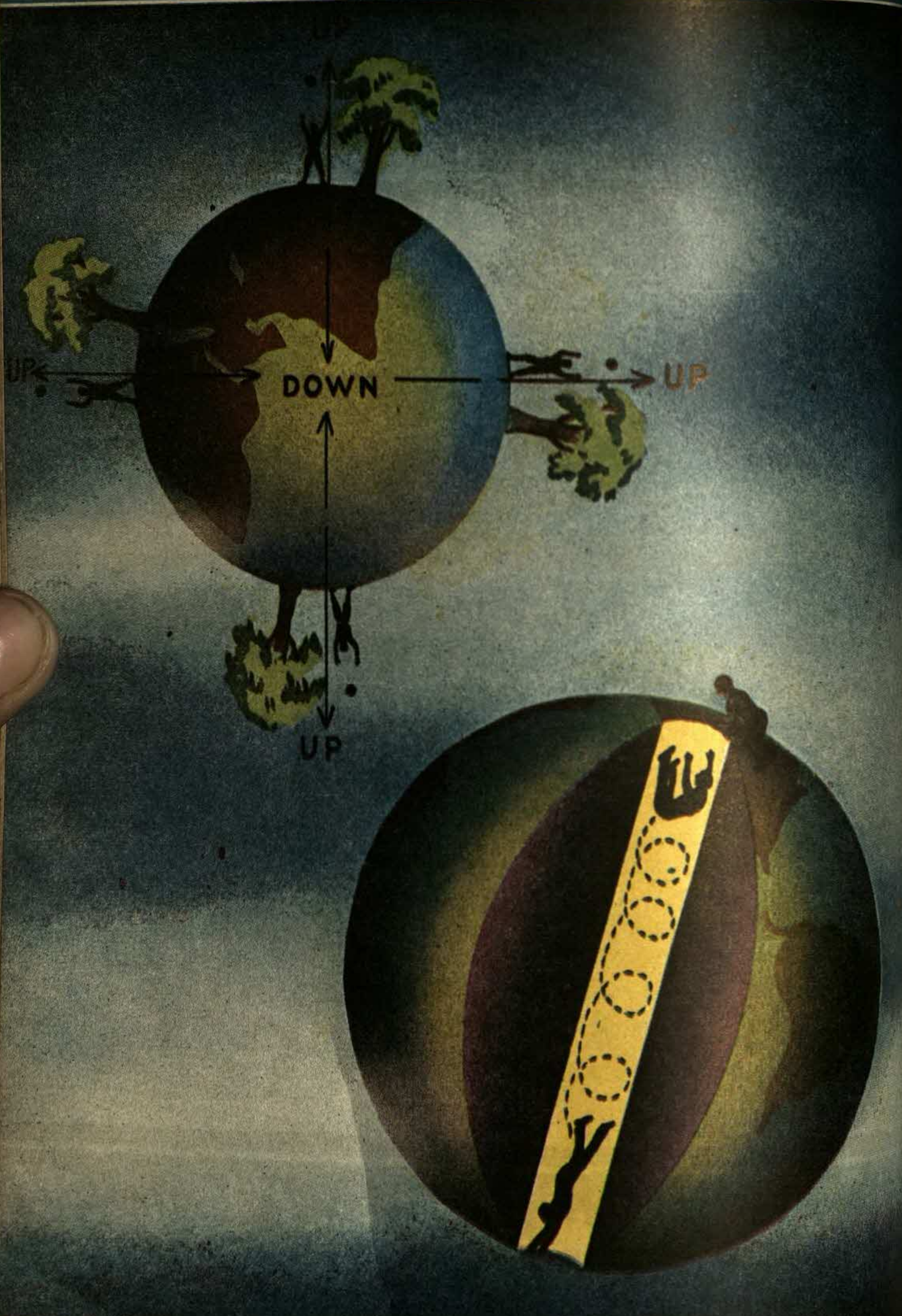
(a) If shad go upstream to spawn, place an E in space 1; if not, a C.
(b) If bacteria reproduce by division, place an M in space 2; if not, an A.
(c) If molds reproduce by budding, place an R in space 3; if not, a B.
(d) If all plants are grown from seeds, place a C in space 4; if not, an R.
(e) If reproduction is the same in higher plants and in animals, place a Y in space 5; if not, an N.
(f) If all reptiles reproduce by eggs hatched outside the body of the mother, place a T in space 6; if not, an O.

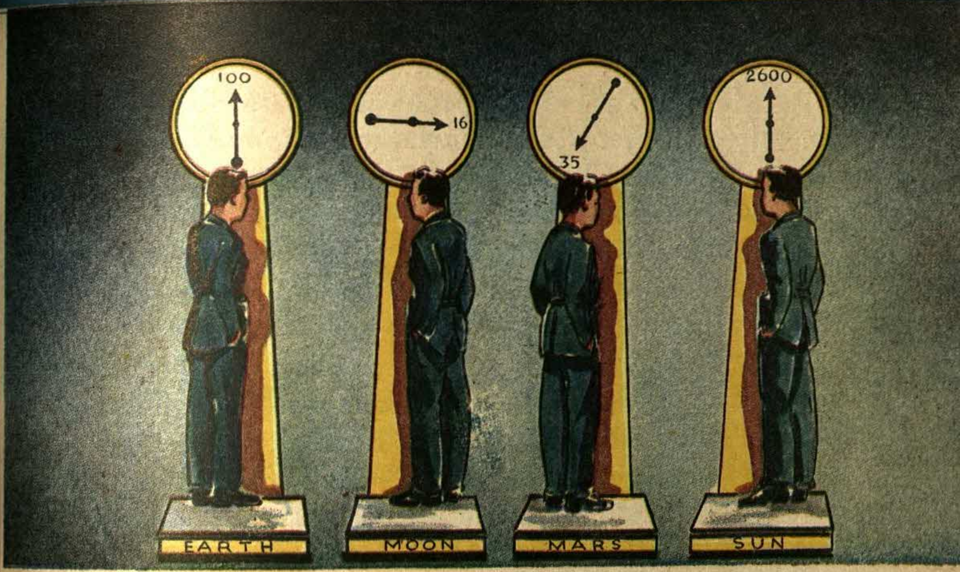
If you have answered all the questions correctly, you will have spelled out a name for the developing young of a plant or animal.

III. Rearrange the jumbled letters in the sentences below so as to make them true statements:

1. Man could not continue to live without *apstln* and *naimsla.*
2. The bee is important to man in *srocs-loplonitnia.*
3. Animals that give much care to the eggs and young usually produce *wfe snffgorip.*
4. Animals and plants are adapted to their *gnusrduonris.*
5. The oldest living thing on the earth today is a *gbi eret.*

ENERGY FOR A WORLD AT WORK


UP
UP
DOWN
UP
UP



Pushes and Pulls

"Suppose a hole were bored clear through the earth."

"But it couldn't be done. You know as well as I that the deepest mine does not go down farther than two or three miles."

"Yes, I know. But can't you use imagination? Can't you suppose that in some way someone has been able to overcome the terrific heat of the earth's interior, and that with plenty of time and money he has succeeded in boring down for a distance of 8000 miles?"

"All right, go ahead with your fairy tale."

"I know how hard it would be to bore such a hole. It is probably impossible. But what I'm getting at is, what would happen if someone stumbled into such a hole?"

"Why, he'd fall in, of course."

"Yes, but how far down would he go? This hole has no bottom. It goes clear through the center of the earth and ends in Australia, perhaps. There the people would see a hole in the ground exactly like ours. They, too, would fall in. Would they fall *up* to us? Would we fall *down* to them? Or, would we fall up to them and they down to us?"

"Wait a minute, this is getting complicated. I believe that a body dropped into such a hole would fall to the center of the earth. Didn't we learn that the earth attracts things toward its center? That means, I suppose, that a man falling into the open shaft at our end and another man falling into the opening in Australia would both drop toward each other. After each had travelled 4000 miles, they would meet at the center of the earth."

"That's so. Now, suppose that only one man started to fall. The farther he fell, the greater would be his speed. By the time he reached the center of the earth, this speed would be tremendous. Do you think he would stop suddenly at the center?"

"No, I guess not."

"He would probably go right on. His speed would carry him on, but the moment he passed the earth's center the force of gravity would begin to slow him up."

"That's right; and there is no good reason why his speed should not decrease at the same rate as it increased during the first half of the trip. So that by the time he reached the surface in Australia, he would slow down to no speed at all."

"Yes; and if he had had the sense to do a somersault while falling, he could reach up, grab at something, and pull himself out in Australia."

"If he didn't grab hold, he'd fall in again. His speed would increase until he reached the earth's center. He'd shoot by the center. Then he would slow up until he reached the opening from which he started."

"I hope he'd have better luck in catching on to something this time."

"Perhaps he would, but you mustn't forget about friction. While falling, he might rub occasionally against the sides of the shaft. Then, too, the air would resist his motion. And by the way, the air at the center of the earth would certainly be more compressed than it is at the surface. It might be as dense as a solid. Such air would slow him up considerably, if it didn't kill him. At any rate, he might not quite reach Australia when starting from our end of the shaft."

"On the return trip, he would hardly reach his starting point. Poor man!"

"Yes. Do you know what such a man reminds me of? A pendulum! He would swing back and forth, back and forth, each swing shorter than the one before. Finally, he would come to rest at the center of the earth."

Why do objects fall?

The boys whose conversation you have just read were using their imagination, but they showed that they were familiar with one of the world's greatest ideas. So far as we know, no one has ever pushed a book off a table without its falling to the floor. No aviator has ever jumped from an airplane in flight without falling.

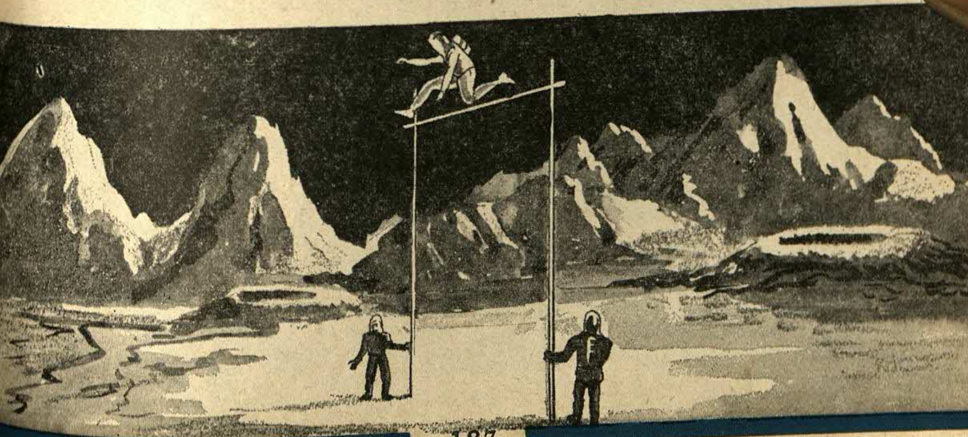
The earth attracts every object on or near it. This pull is called the force of *gravity*. Though it is believed that the force of gravity has been acting ever since the universe came into being, even to the present day, it is still pretty much of a mystery. We owe to Isaac Newton our first knowledge about this force. Newton applied the idea of gravity to the whole universe. He showed how it explains the movements of the earth and planets around the sun, and of the moon around the earth. "All bodies in space," he said, "attract each other. The strength of the attraction between any two bodies depends on two things: the amount of material in the bodies and the distance between them."

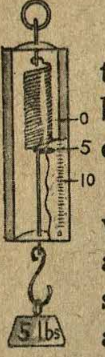
Newton's law of gravitation holds for all objects. The tiniest speck of dust is attracted to the earth, and so is the largest mountain. On the one, the force of gravity is small, since the amount of material in a dust particle is small. On the other it is large, for a mountain has a great deal of material.

How do we measure the force of gravity?

You will recall the story of the imaginary trip that we made to the moon. Everything seemed to weigh so little on the moon. Stones which we could not budge on the earth could be lifted with the greatest ease. While walking, we seemed to be wearing "seven league boots," for a single leap would carry us several yards. We could jump six times as high as we could on the earth and we could throw objects six times as far. These strange experiences are explained by the fact that the moon is very much smaller than the earth. This makes the force of gravity on the moon one-sixth that on the earth.

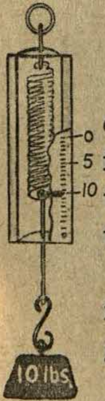
Your weight is the force of attraction of the earth on your body. Anything which changes the strength of this attraction changes your weight. Thus, by going





to the top of a tall mountain, you increase the distance between the center of the earth and your body. At an elevation of three miles, you lose an ounce in weight.

One of the most common ways of measuring the weight of an object is to use a spring scale. This operates on the principle that one weight will stretch a spring twice as much as another, if its weight is twice as great.



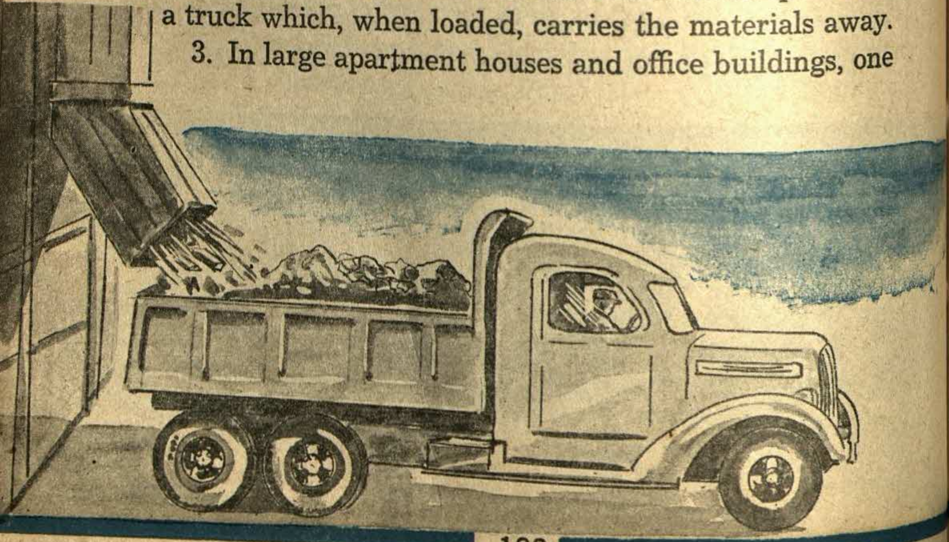
How may gravity help us or hinder us?

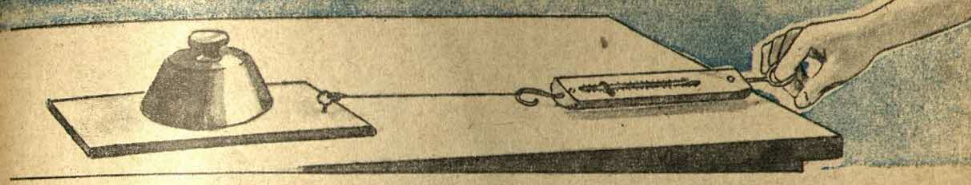
No method has yet been found to shut off the force of gravity. The best that man can do is to turn this force to his advantage whenever possible. Below are three statements, each of which illustrates a use for the force of gravity:

1. By mounting a water wheel below the falls, the flowing stream is made to saw wood, pump water and grind wheat.

2. In wrecking a house, the bricks and other debris are thrown into a wooden chute. The chute empties into a truck which, when loaded, carries the materials away.

3. In large apartment houses and office buildings, one





can mail a letter at every floor. You insert the letter in a slot and it is whisked away by the force of gravity to the mailbox on the ground floor.

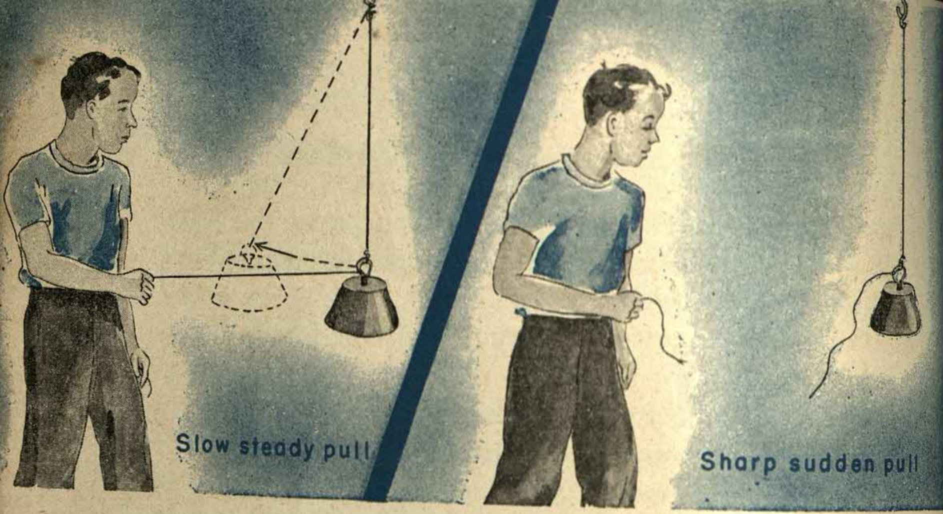
Sometimes gravity is a very undesirable force. Below are three statements which illustrate ways in which the force of gravity hinders man:

1. There goes my collar button. I wonder where the force of gravity took it this time.
2. This expensive vase dropped only six inches, but it was smashed to pieces.
3. You may not realize that the force of gravity is acting until you put on skates.

Can objects start moving by themselves?

Obtain a spring scale, a weight and a smooth board. Fasten a string to one end of the board so that it may be drawn along a table by means of the spring scale. Rest the weight on the board and begin to pull gently on the spring scale. Note how many ounces' pull is registered on the scale just before the board begins to move. The heavier the weight, the greater is the amount registered on the scale.

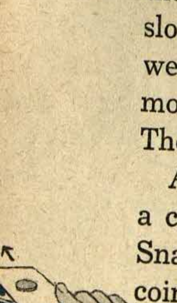
This experiment shows that a body at rest tends to remain at rest, and that a force must be exerted to overcome its tendency to remain at rest. This tendency is called *inertia of rest*. Of course, the reading on the balance shows the force necessary to overcome both

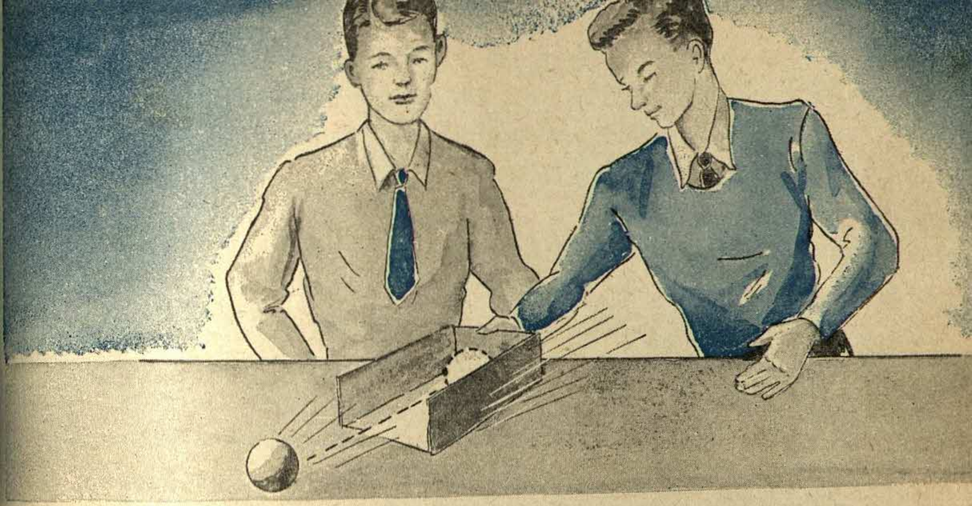


inertia and friction. The drawing on page 196 tells how resistance due to friction alone is measured. If you pull on the scale quickly, the amount registered is much greater, indicating that there is a greater force of inertia to be overcome. In fact, it is the amount of change of motion that determines the amount of inertia. By starting the weight gradually, the spring scale shows that the force of inertia to be overcome is less.

Try this experiment. Suspend a weight as shown in the drawing. Tie a thread to the weight and pull it slowly. If you do this slowly enough you can move the weight without breaking the thread. However, try to move the weight suddenly by a quick jerk of the thread. The thread snaps and the weight remains at rest.

Another interesting experiment with inertia is to rest a coin on a card laid over the top of a glass tumbler. Snap the card with your finger. Out it goes, but the coin stays where it was; that is, it falls into the tumbler.





Finally, consider the experience of falling backward as a train in which you are riding moves forward. Inertia causes you to stay where you are. Were it not for the friction between your shoes and the floor, the car floor would slide along under your body, leaving you behind.

Can moving objects stop by themselves?

Cut away one end of a long shoe box as shown in the drawing. Insert a rubber ball. Now quickly shove the box forward on the table, open end first. As you bring the box to a sudden stop, the ball keeps on going and flies out at the open end. Evidently, a body in motion tends to remain in motion. This tendency is called *inertia of motion.*

Below are three statements, each of which illustrates the inertia of motion:

1. With the report of the pistol, the runners started. Jack took the lead at once and kept it to the end. His

chest broke the string at a speed which carried him several yards farther before he could stop.

2. As the sled neared the bottom of the hill it was going at top speed. Though the road then began to slope upward, the speed carried the sled almost to the crest of the next hill before it came to a stop.

3. The second baseman leaped high and speared the line drive. The ball was moving so fast, however, that it toppled the player over backward.

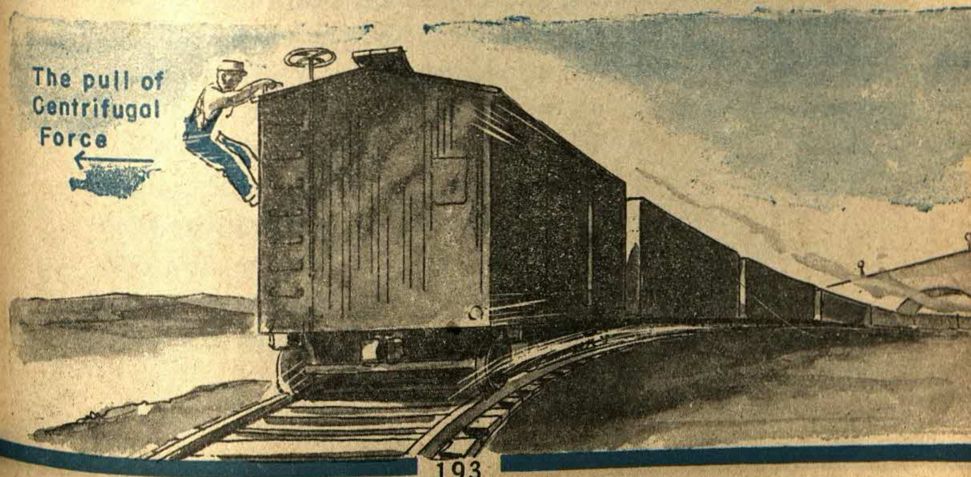
How do we overcome inertia?

A rug full of dust is hanging on a clothesline. You wish to separate the rug from the dust. You therefore grab the carpetbeater and swing it forcefully against the rug. The force of the impact is sufficient to change the rug from a state of rest to a state of motion. It moves away so quickly that the dust is left behind.

In each of the examples of inertia described in this chapter, you will find that a force is employed every time the motion of a body is changed. From rest to motion, from slow motion to rapid motion, from motion to rest and from rapid motion to slow motion—all involve the action of a force. Without this force there would be no change in motion.

There is, however, one more case of inertia which is sometimes difficult to understand. It has to do with a change in the direction of motion rather than its speed.

Suppose that you are in a train which is going at a constant speed. You will not know that you are in a moving train if you do not look out of the window. If the wheels were perfectly round, the tracks perfectly smooth, all sounds entirely muffled and all outside sights removed, you would think you were at home in a quiet room, provided the speed of the train did not change. Now, let the tracks curve. The moment the direction of motion changes, you feel a sidewise pull. If the change of direction is great enough, you may be thrown against the window or into the aisle. The reason for this is that your body tends to keep moving in the same direction. The force that causes this is called a *centrif-*



ugal force. The force that tends to pull the train inward around the curve is called *centripetal.*

Why does the earth not fall into the sun?

The earth and the other planets are moving around the sun at a steady speed. Their paths are nearly circular. Now, in circular motion a body changes its direction at every point in the circle. What force is acting to change constantly the direction of motion of the planets? It was Isaac Newton who pointed out that it is the force of gravitation which is producing this change of direction. The force of attraction between the sun and the planets changes the direction of their motion into a nearly circular path. Should the sun's attraction cease, each planet would shoot off into space in a straight line. If there were no centrifugal force, the earth and the other planets would fall into the sun.

Why is it difficult to push or pull an object?

When we shove a block across the floor, it soon comes to rest. Some force must act upon it to stop it. An ice skater may glide easily over the ice, but unless he continues to supply more energy to keep moving, that same unseen force soon stops his motion. We think of the surface of the floor, or of ice, or of glass, as being perfectly smooth. It is far from that. No surface is perfectly smooth. Whenever two surfaces rub together, therefore, a force appears which tends to prevent or resist the motion.

The resistance which makes itself felt when we move one body over or through another is called friction.

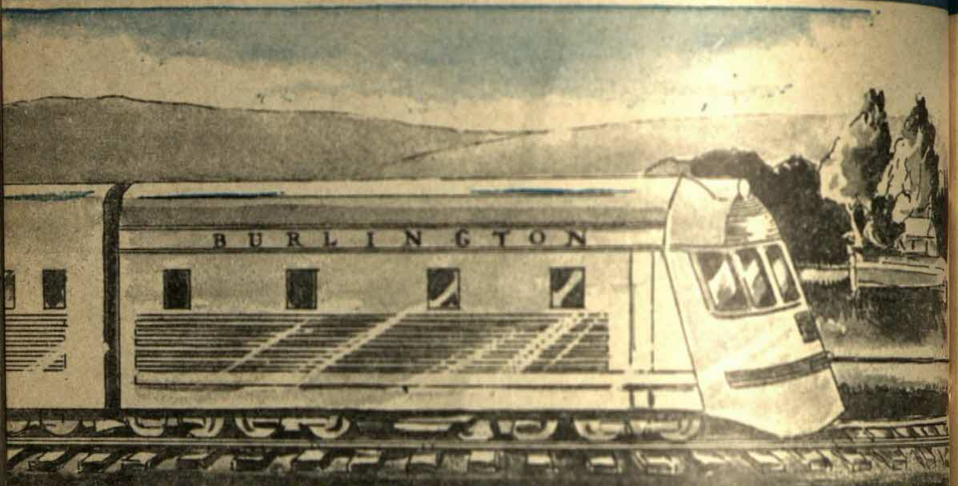
The constant wear and tear of objects around us is proof of the action of friction. Lead pencils become dull as they are rubbed over paper. Particles of a pencil eraser wear away with the marks we try to remove. The rubber tires of an automobile become thinner as they roll. Even our teeth wear down from constant friction involved in chewing food.

And yet, friction has its uses. It is used in slowing down a vehicle and in making it easy for wheels to grip the ground. There are other values of friction. Walking would be impossible without friction, as you may realize when you try it on an icy pavement.

Upon what does the amount of friction depend?

Smooth surfaces produce less friction than rough ones. Try to write with chalk on a windowpane, and compare the result with chalk-writing on a blackboard. One can almost say that friction makes writing possible.

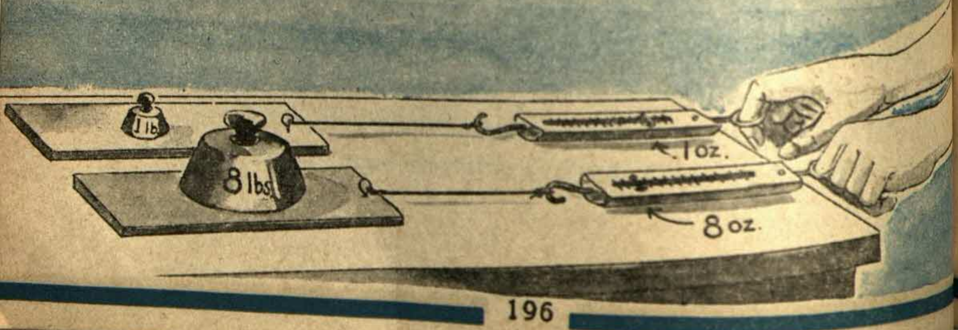
When a motorist reaches a detour sign, he is usually



OVERCOMING THE FRICTION BETWEEN A

annoyed. He knows that a rough roadway awaits him and that the friction between wheels and road will be great. And yet, the same man is glad to encase his tires in chains so as to avoid skidding on an icy pavement. In the latter case, he purposely roughens the surfaces of the wheels so as to increase friction.

Attach a spring balance to a board and pull the latter over the table. Note what the balance reads when the board is moving. Now, add a weight to the board and repeat the observation. Add a second weight. In each case, the spring balance indicates the force of friction to be overcome in order to keep the board moving.


1 lb.
8 lbs.
1 oz.
8 oz.

LOCOMOTIVE WHEEL AND THE TRACK

It is more difficult to drag a heavy body than a light body, because the heavy body presses the rubbing surfaces together more. When an automobile driver jams on the brakes, he presses the rubbing surfaces hard against each other.

How can we reduce the amount of friction?

One reason why oil reduces friction is that the oil particles fill the pits and cavities of the surfaces in contact, thereby making them smoother. Though the shaft of a machine and the bearing in which it turns are usually polished smooth, there are always many tiny rough spots which no amount of polishing can remove. Hence a film of oil between moving metal parts becomes very necessary. Actually, the oil film keeps the surfaces from touching and rubbing. Of course, the wheel itself reduces friction, since rolling friction is always less than sliding friction. See page 249.

Little Forces into Big Ones

About two thousand years ago there lived in Syracuse, a city of ancient Greece, a man named Archimedes. He was one of the world's earliest inventors. One day Hiero, the king of Syracuse, was discussing with Archimedes some ideas he wanted Archimedes to work on.

"Your Highness," said the inventor, "I am not a very strong man, but I can move any weight whatever. If there were another earth on which I could stand, I could even move the earth wherever you pleased."

The king was amused, but he liked Archimedes and had respect for his great mind.

"Prove it," he said. "Move something big and heavy. One of my large galleys is several hundred yards from shore. Let me see you pull it in."

The strange thing is that Archimedes made good his boast. With levers and ropes and pulleys he not only dragged the ship toward shore, but pulled it up on the sand.

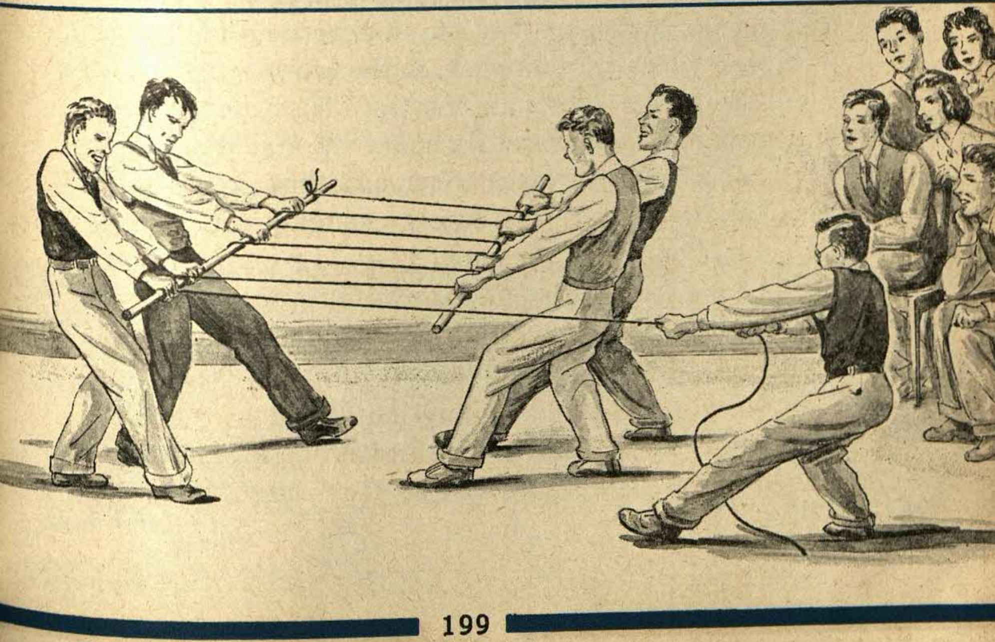
A modern Archimedes

"Members of the Newton Science Club, I wish to demonstrate to you how I can multiply my strength so as to beat any four of you in a tug of war. As you know, I am not very heavy, but I will take on the four heaviest members of the club if you will let me use an invention I have made."

It was Bill Smith addressing the school science club at one of its demonstration meetings. A ripple of laughter passed through the audience as they heard Bill's re-marks. Everybody knew how poor an athlete he was, but they also knew that Bill was not given to idle boasting.

Four of the strongest boys, therefore, stepped forward to accept the challenge. The club settled back to watch the fun.

"Now, John, you and Fred hold this stick. Sam, you and Robert will please hold this second stick, facing John and Fred. I now tie one end of this clothesline to one stick and wrap the rest of it around both sticks as follows. [See the drawing.] Brace yourselves and get ready to pull the sticks in opposite directions. I shall hold the loose end of the line and when the president gives the signal, we shall all pull. I will try to bring the sticks together so that your hands will touch. You will try to separate the sticks so as to pull the rope out of my hands, if possible."



"Ready, go!" cried the president.

John, Fred, Sam and Robert pulled with all their might, but strangely enough, Bill held his own against them. For a minute there was no movement of the sticks. Then the rope slipped a bit in Bill's direction. At that instant, Bill made a spurt, pulling harder than ever. To everyone's surprise, the sticks began to approach each other. The four boys tugged frantically, but they were steadily losing ground. At last their hands touched; and with a last jerk which squeezed their knuckles together painfully, Bill stopped and bowed to the applause of the audience.

What is a force?

To understand how Archimedes and Bill Smith accomplished their feats of strength, we must first know what a force is and how it acts. In science we use the word *force* in a special way. Let us try to grasp this special meaning so that we may understand better the machines which do the work of the world.

All around us objects are moving. They move slowly and they move rapidly; they move up and they move down; they rub over each other and they collide with each other; they are constantly changing their direction of motion. Even when a body is at rest its molecules are moving. All this motion involves *forces*. A force is needed to start movement and a force is needed to stop it. A force is needed to speed up a body; to slow it down; to make it move in a new direction. When we lift or climb, we exert a force to overcome gravity. If movement is neither up nor down it still requires a force to overcome friction. A force, then, is a push or a pull which can change the motion of a body.

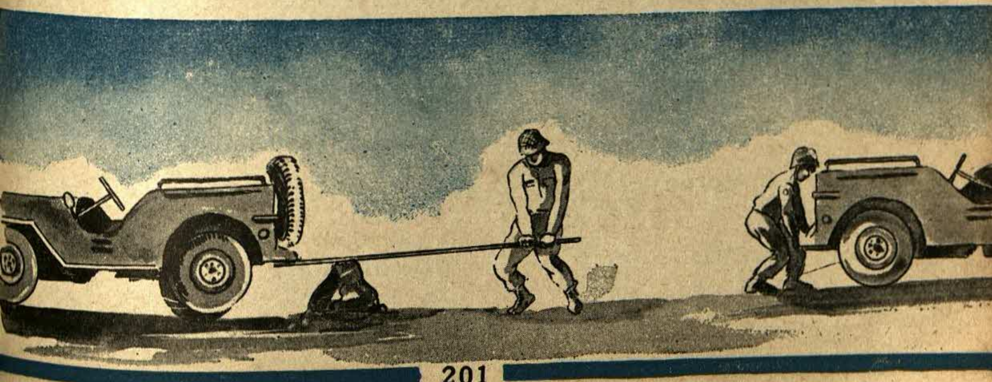
In order to overcome gravity, friction and inertia, man exerts forces with his muscles; but he often finds that his muscles are weak. To live comfortably and securely, he frequently needs forces far greater than his body alone can exert.

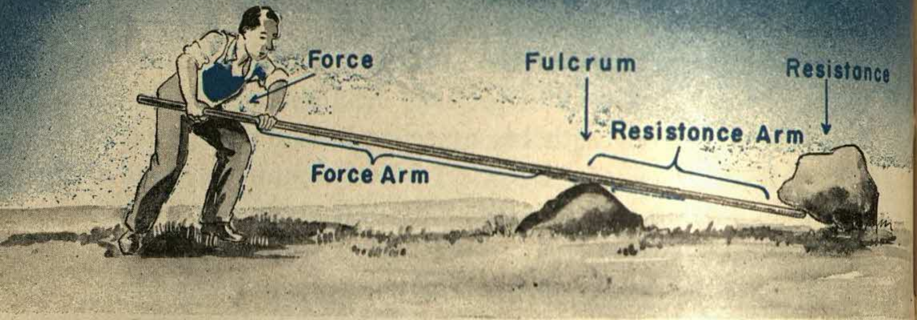
In time, man learned ways of multiplying his bodily strength. He learned how to change small forces into big ones and big ones into small ones. Like Archimedes and Bill Smith, he has used his intelligence to build machines. With a machine, man can move heavier objects than with his muscles alone; he can move them faster or more slowly, as he wishes.

Today we live in a "machine age." Most of the world's work is done by machines, but it took thousands of years before we arrived at our present stage. To understand such complicated machines as the steam engine and the automobile, we must begin with a study of the part that forces play in the simple machines.

How can we multiply a force by using levers?

In the drawing you see two men, each trying to lift the rear end of an automobile. The first is using his

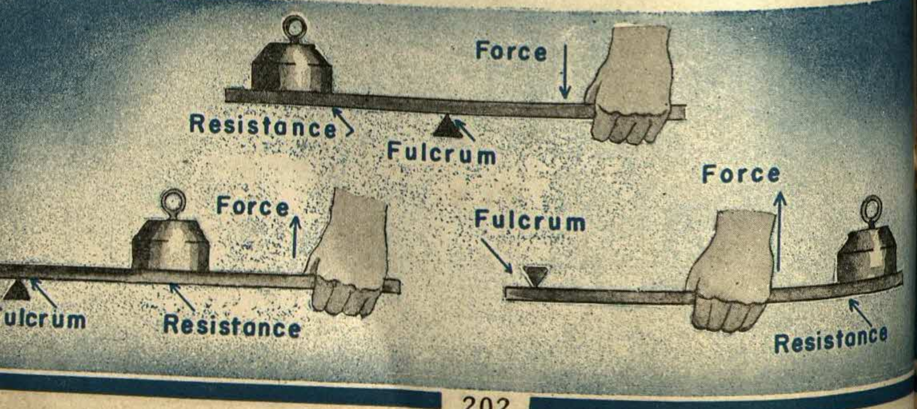




muscles alone and will probably fail. He may even injure himself. The second man is using a long pole as a lever. He is bound to succeed.

There are several parts to a lever. The first part is the *fulcrum,* the point where the lever is pivoted or supported. The second part is the point at which the *force* is applied, and the third is the point where the *resistance* or weight to be overcome is placed. The distance between the fulcrum and the force is known as the *force arm.* The distance between the resistance and the fulcrum is known as the *resistance arm.* Study the drawing.

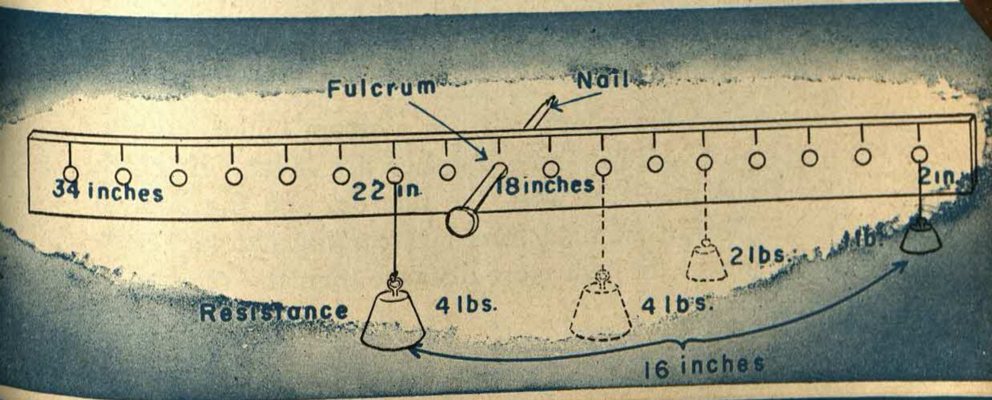
Though all levers have the parts listed above, they are not always in the same places. In the drawing below you will find three ways of arranging fulcrum, force

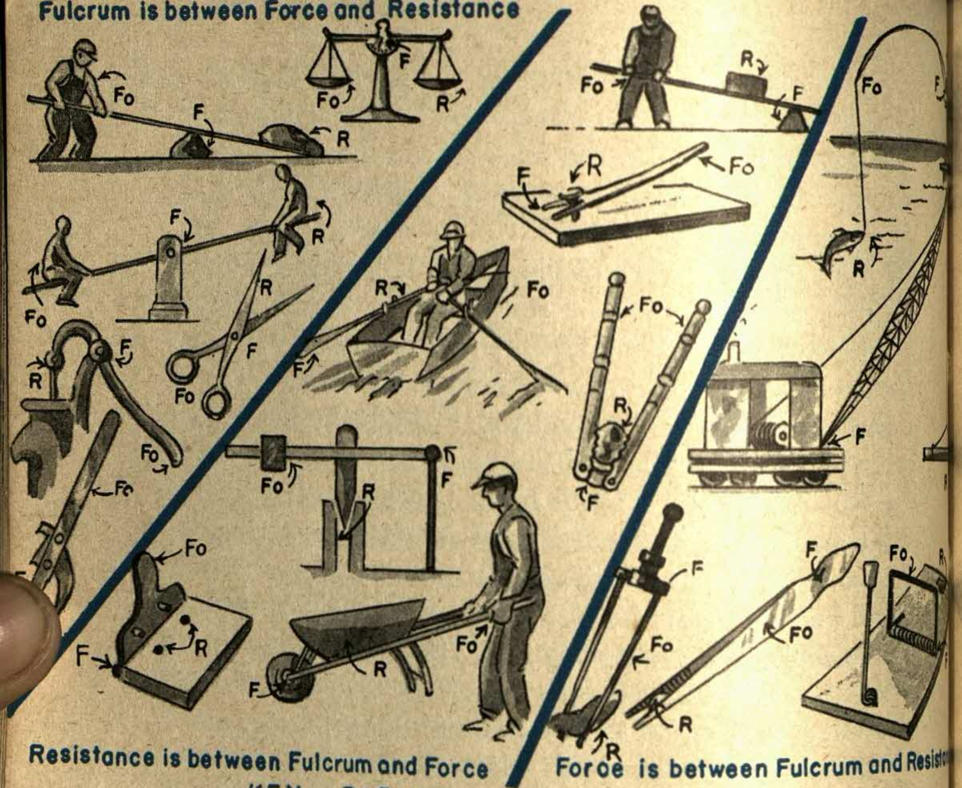


and resistance. In the first case the fulcrum is between the force and the resistance. In the second case the resistance is between the fulcrum and the force. In the third case the force is between the fulcrum and the resistance.

Bore a hole at each of the even-numbered inch marks on a yardstick. Insert a round nail in the hole at the 18-inch mark and support the nail so that the arrangement resembles a seesaw. The yardstick should balance perfectly. Hang a 4-pound weight from the hole which is 4 inches to the left of the nail. To balance the stick a 4-pound weight may be hung 4 inches to the right of the nail. But there are other ways of restoring the balance. A 2-pound weight placed 8 inches to the right will be sufficient, and also a 1-pound weight suspended 16 inches to the right of the nail. See the weights shown in dotted lines in the drawing. Where would you hang an 8-pound weight, to restore the balance?

Thus, it can be seen that a large resistance of 4 pounds may be overcome by applying a small force of 1 pound. The effect of the lever, therefore, is to multiply the force which is exerted. The crowbar, the beam balance, the can opener, the pump handle, the seesaw and the scissors




Fulcrum is between Force and Resistance
Resistance is between Fulcrum and Force
Force is between Fulcrum and Resist
Fo
F
R

KEY— R= Resistance, F= Fulcrum, Fo= Force

are levers in which the fulcrum is between the force and the resistance.

In this type of lever the resistance overcome is usually greater than the force applied. The force then moves through a greater distance than the resistance.

The crowbar, the tack-puller, the wheelbarrow, the nutcracker, the safety valve in a steam boiler, oars in a rowboat and the hole puncher are levers in which the resistance is between the fulcrum and the applied force. Here, too, a small force, overcoming a larger resistance, moves through more distance than the resistance.

The fishing rod, springtrap, sugar tongs, tweezers, and fire tongs are examples of levers in which the force is between the fulcrum and resistance. Here, a large force, overcoming a smaller resistance, moves through a shorter distance than the resistance.

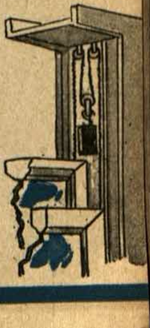
How can we multiply a force by using pulleys?

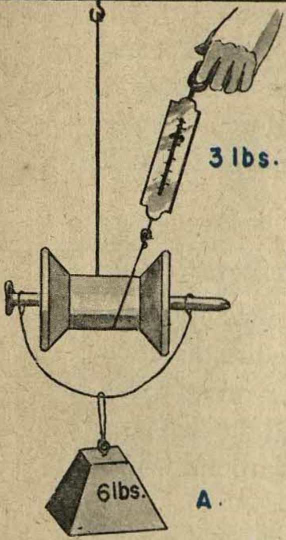
A pulley may be fixed, or it may be movable. The fixed pulley is commonly used to change the direction in which a force is applied. Have you ever raised a flag on a flagpole? You pull the rope *down* and the flag goes *up*. At the top of the pole is a fixed pulley around which the rope goes.

Another interesting use of fixed pulleys is in the window sash. The drawing shows how the pulleys are fixed in the window frame. The falling weight helps to lift the sash.

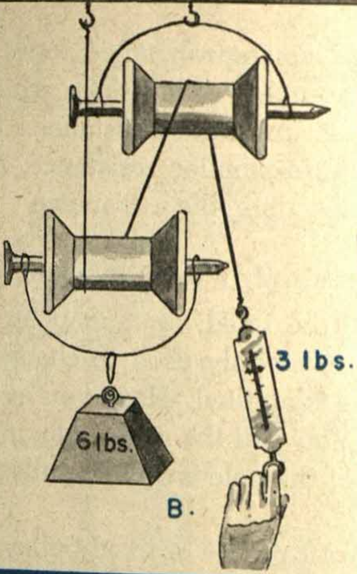
Fixed pulleys do not increase the force exerted upon them. If anything, the force applied is somewhat reduced because of friction between the wheel and bearing. A fixed pulley offers convenience rather than an increase of force.

A single movable pulley may be made from a spool as shown in drawing A, page 206. Slip a nail loosely through a spool and tie a 6-pound weight to the nail, as shown. Now tie one end of a stout string to a fixed point and wrap the string around the spool. To the loose end attach a spring balance. What does the spring balance read as you pull it up to lift the weight? It reads much less than 6 pounds—only about 3 pounds, in fact. Six divided by *two* equals three.

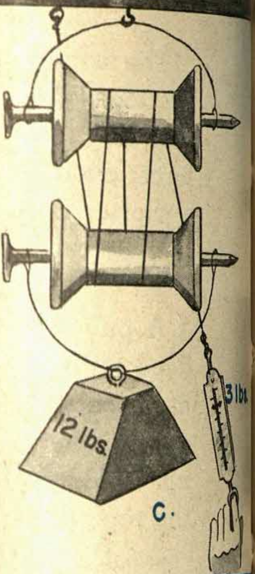




A.



B.



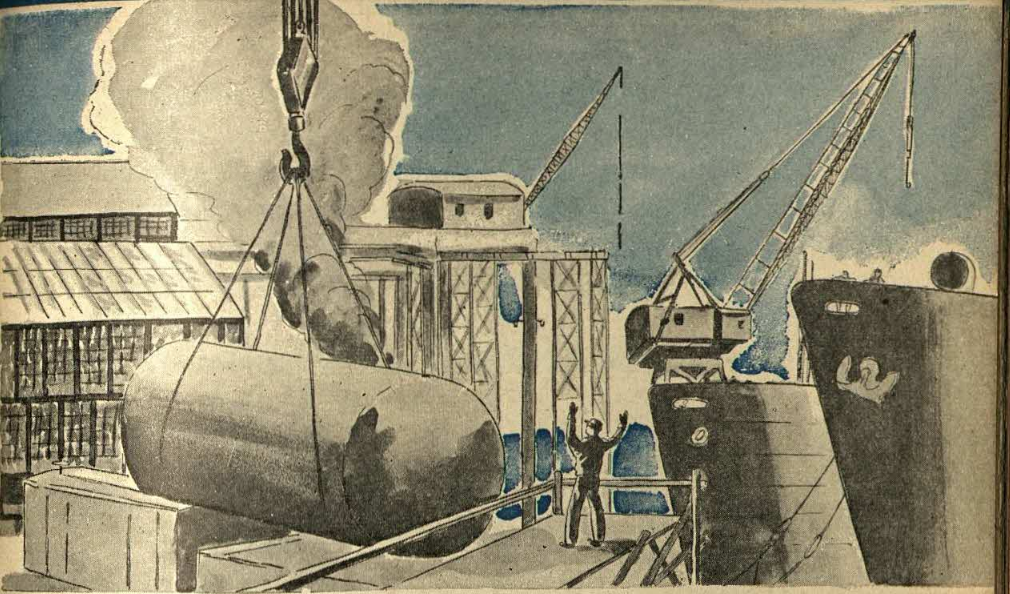
C.

In drawing B, a single movable pulley is combined with a single fixed pulley. Again there are *two* strands attached to the movable pulley, and again the force is one-half the resistance.

In drawing C, the spools are arranged as a block and tackle. The entire arrangement consists of two movable pulleys and two fixed pulleys. In this case, *four* strands are attached to the movable pulley. Hence, the applied force is only *one-fourth* of the resistance overcome; that is, a pull of 3 pounds can lift 12 pounds.

The block and tackle is frequently used. Pianos, safes and other heavy objects may be raised with it, using the pull of only one man. The great cranes and derricks which hoist steel girders into place employ the block and tackle in the same way.

Bill Smith's demonstration utilized the movable pul-

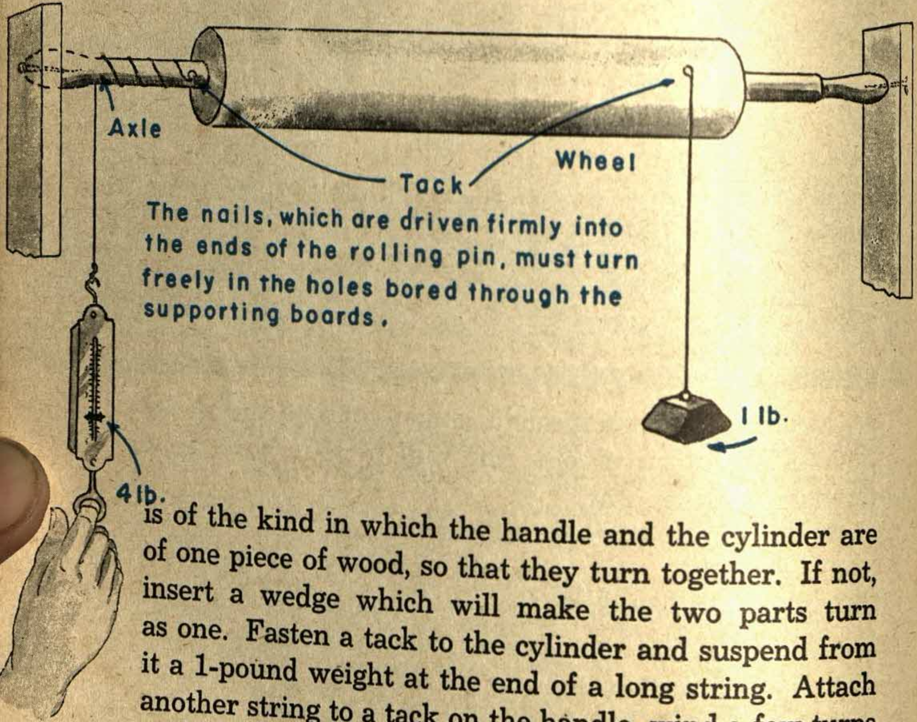


ley idea. By means of his arrangement of rope and sticks he was able to overcome the pull of four boys, each stronger than he was.

When the rope passes around the smooth stick, it is really a pulley. Not counting the point on the stick where the rope is tied, there are therefore three pulleys on each stick. The arrangement is like a block and tackle. Let us suppose that John and Fred held the block end and that Sam and Robert held the tackle end. In that case there were 6 strands attached to the movable pulley and this gave Bill's end a mechanical advantage of 6, not counting friction. In other words, Bill's pulling strength on the two sticks was multiplied *six times.* Friction reduced it to some extent, but he could count on a pull of at least five times his normal strength, against which his opponents were helpless.

How can we multiply a force by using a wheel and axle?

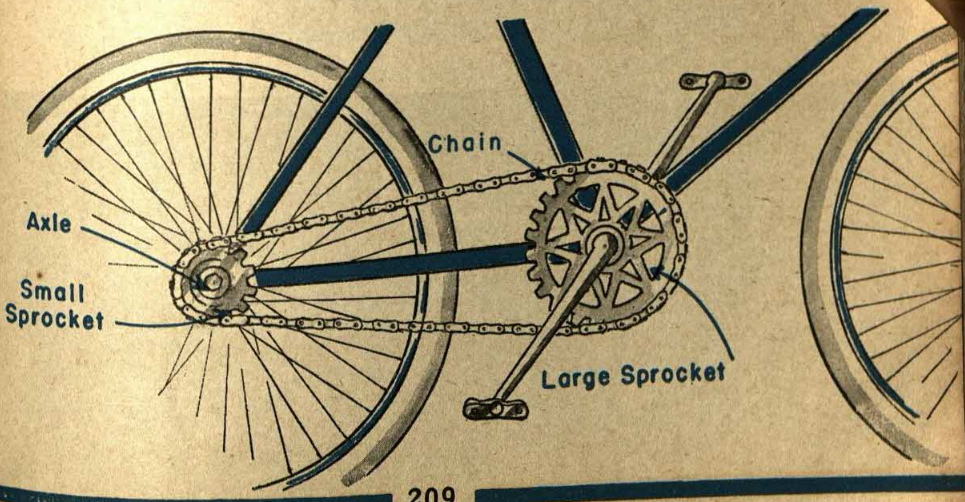
Borrow a rolling pin from the kitchen and set it up as shown in the drawing. Be sure that the rolling pin is of the kind in which the handle and the cylinder are of one piece of wood, so that they turn together. If not, insert a wedge which will make the two parts turn as one. Fasten a tack to the cylinder and suspend from it a 1-pound weight at the end of a long string. Attach another string to a tack on the handle, wind a few turns on the handle and fasten the loose end to a spring balance. If the diameter of the cylinder is four times as great as the diameter of the handle, the spring balance will read 4 pounds. Thus, a force of one pound applied to the wheel overcomes a resistance of 4 pounds attached to the axle.



The nails, which are driven firmly into the ends of the rolling pin, must turn freely in the holes bored through the supporting boards.

Now, remove the spring balance and hold the loose end of the wound-up string in your hand. Pull the string so as to unwind it about two turns. What happens to the 1-pound weight? It has risen quickly through a considerable distance. Thus, a force applied at the axle may produce rapid motion of the resistance attached to the wheel. The force in this case is as many times greater than the resistance, as the distance moved by the resistance is greater than that moved by the force.

Let us apply the action of the wheel and axle to a bicycle. As you move the pedals, the large sprocket receives the applied force. The chain transmits this force to the small sprocket. Since the diameter of the small sprocket is usually about one-fourth the diameter of the large sprocket, the small sprocket turns about four times as fast as the large sprocket. The rear wheel, which moves with the small sprocket, also turns four times as fast as the large sprocket and the bicycle moves forward very rapidly. Hence, for every complete turn of the pedals, the rear wheel turns completely around four times. However, the effort your feet exert must be



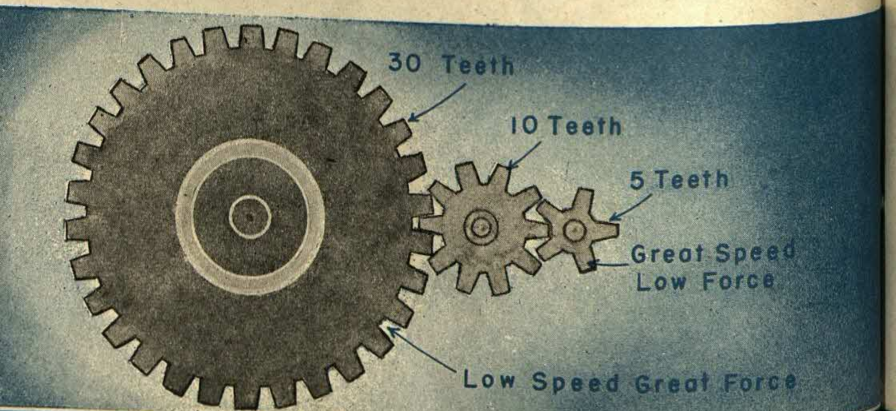
eight times as great as the resistance the drive wheel must overcome. This is due to the fact that the pedals in making a complete turn move around a circle only about one-half as large as the drive wheel. This shows why it is so hard to ride a bicycle up a steep hill.

A grindstone is another example of a wheel and axle used to produce increased speed. As you crank, you pull hard, but the hand revolves slowly. The stone spins rapidly, but a slight increase in pressure at the rim of the wheel makes it almost impossible to continue cranking.

In many well-known machines, wheels and axles are used to increase forces rather than to increase speeds. In the meat grinder the handle is turned rapidly through a large circle. The axle with its cutting edges revolves in a smaller circle but with greater force, thus chopping the meat into fine pieces.

Did you ever notice how much harder it is to turn the hour hand of a clock than the minute hand? The minute hand revolves twelve times as fast, and therefore it requires only one-twelfth the force to move it.

Gears are a modification of the wheel and axle. In the drawing you see three toothed wheels arranged so



that the teeth mesh. All three wheels turn whether the force is applied to the 30-tooth wheel or to the 5-tooth wheel. However, the speeds and forces are not the same for all wheels. When the 30-tooth wheel has revolved once, the 10-tooth wheel has revolved 3 times and the 5-tooth wheel, 6 times. A 1-pound force applied at the 5-tooth wheel becomes a 2-pound force at the 10-tooth wheel and a 6-pound force at the 30-tooth wheel.

A variety of gears are used nowadays in various important machines.

How can we multiply a force by using other simple machines?

Attach a spring balance to a toy cart and drag it along. After the cart is moving, the balance reads an amount equal to the force of friction which is being overcome. As you begin to drag the cart up an incline, the balance shows a greater pull, since the force of gravity is resisting the upward movement. Now lift the toy cart vertically in order to see just how much is the pull of gravity on the cart. You will find that the balance reads a greater amount than it did on the incline. In other words, the inclined plane makes it easier to lift a weight. The more gradual the incline, the less force is exerted to overcome gravity; but it takes longer to reach a desired elevation.

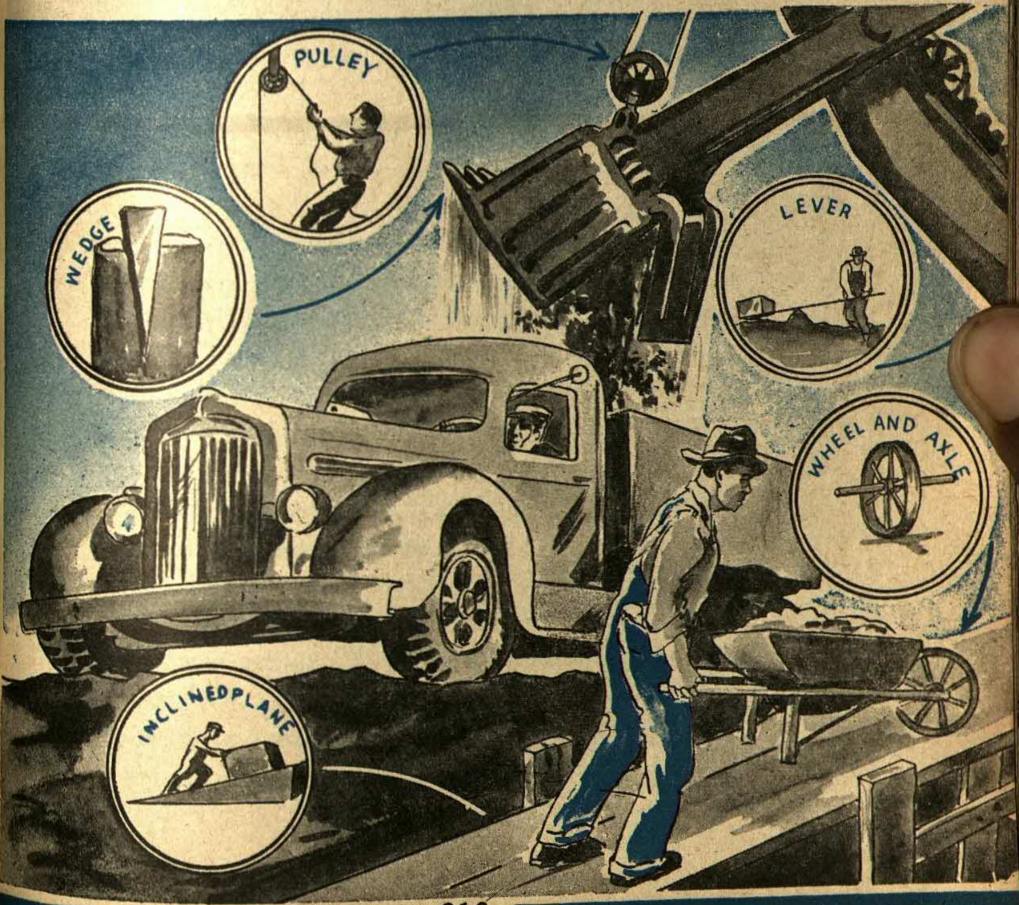
Inclined planes are used very frequently. Every staircase is a kind of inclined plane. How much more difficult it would be to climb steep ladders rather than stairs. We could reach our rooms more quickly with ladders, but only by greater exertion of force. The wind-

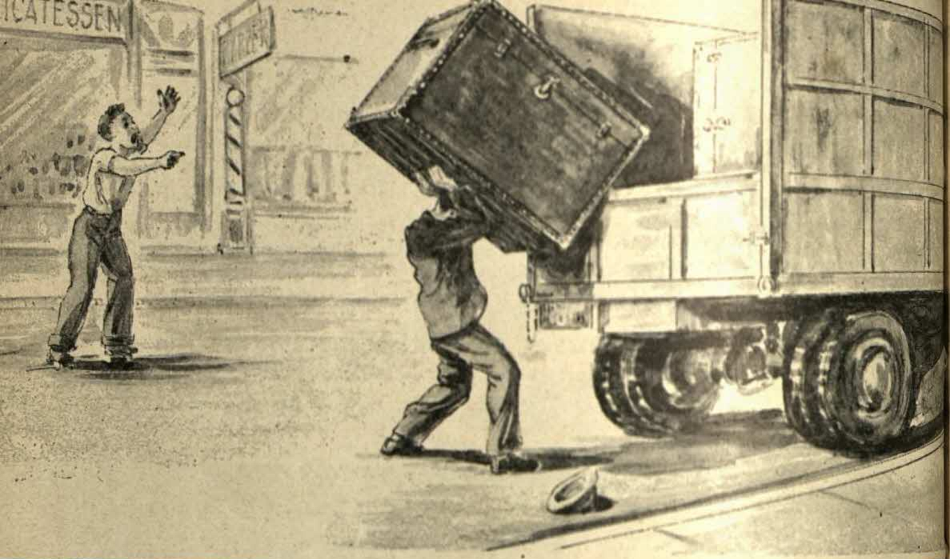
ing roadways up a mountainside are inclined planes. It takes less force to climb these roadways than it would take to climb directly up the face of the mountain. Rolling a barrel up an incline to a truck is still another instance of the use of an inclined plane.

When we descend stairs or coast down a hill, we are permitting the force of gravity to act more gradually on our bodies than it would act in a sheer drop from the same elevation. Thus, an inclined plane works both ways. It helps us to lift a body against the force of gravity with a force smaller than the body's weight and it helps us to lower bodies gradually so as to avoid too rapid a fall.

The screw and the wedge are also simple machines. In action they resemble an inclined plane. The screw helps us to overcome a large resistance by exerting a smaller force. An important use of the screw is in the lifting jack, which can be used to lift an automobile or raise the side of a house.

With a wedge we can split a stout log. Pins, needles, spears, arrowheads, knives, chisels and many other carpenter tools are examples of the wedge.





Work and Energy

"Watch out for that trunk!" came the warning cry, when a man seemed about to be hit by a trunk tottering above his head on the edge of a truck. He reached up to ward off the blow and found himself being pushed down by a great weight. He was just strong enough to keep it from crushing him to the ground. The trunk did not budge, and neither did he. It was a clumsy situation. Straining every muscle and with perspiration running down his face, the man kept his position. It was two minutes before the truck driver could bring him relief. "Whew! That was hard work!" said the man. "Why, he did not work at all," said a professor of science who had witnessed the accident.

. . . . .

John came home to supper after playing a game of football. Jim came home after spending the day studying in the library. "Gosh, I'm tired," said John. "So am I," countered Jim. "Oh, how can *you* be tired?" replied John, "you did no work at all, just sitting in a chair with a book! I *worked!*"

. . . . .

In the paragraphs above, it is quite evident that each of the characters is thinking of something different when he uses the word *work*. There are many words in science which are used loosely and often incorrectly. Ask some of your friends what they mean when they use the word *energy*. The variety of answers will amaze you.

Fred may say, "Energy? Why, that's something like a force," while Bob thinks it is "like strength or power." Bill may have heard a great deal about energy. He may know that you can get it from Niagara Falls or Muscle Shoals. He may know that plants get energy from the sun, that certain things lack energy, and that we eat food in order to obtain energy. Yet, he cannot put his finger on just exactly what is meant by the word *energy*.

Now, scientists try to use words so their meanings will be exact. Before we go any further, then, let us be sure that we know exactly what we mean by the words, work and energy.

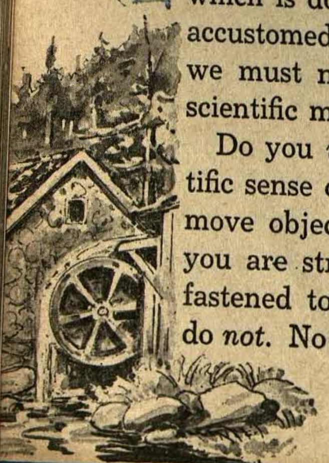
What does the scientist mean by the word work?

One difference between plants and animals is that animals are much more free to move around. They move themselves from place to place and they move objects which are in their way. In order to escape from an enemy, they start from rest and get into motion; in order to catch their prey, they cause moving things to stop. In building their homes, they move materials from one place to another; in adapting themselves to land, to water and to air, they develop different ways of moving about.

Whenever the motion of an object is changed, a push or a pull is exerted. As we have learned, the scientist calls this push or pull, a *force*. If an object is at rest, a force is needed to start it moving. If an object is moving, a force is needed to slow it down or to stop it. If an object is moving in a certain direction, a force is needed to change that direction.

Work is done whenever an object is moved through a distance by a force. Since all motion involves overcoming the resistance due to gravity, inertia or friction, we may say that whenever a force overcomes resistance and causes a body to move, work is accomplished. In lifting a book *work* is done. *Work* is done when the wind blows, because air is moving. *Work* is done when a river flows, because water is moving. When a scientist uses the word *work*, he has in mind only that which is done when a body moves. Of course, we are accustomed to other meanings of the word *work*, but we must not confuse these other meanings with the scientific meaning.

Do you *work* when you are thinking? In the scientific sense of the word, you do not, because you do *not* move objects outside your body. Do you *work* when you are straining every muscle to lift a chair that is fastened to the floor? According to the scientist you do *not*. No matter how tired you may get, you have not



succeeded in overcoming the resistance of the chair to moving. Should you succeed in tearing the chair from its fastenings, you would then be doing *work.*

Let us now consider what forces man has at his command to overcome resistance and to do the work of the world. He can use the force of his own body, or he can call upon forces outside of his body. Each of these is discussed in the pages that follow.

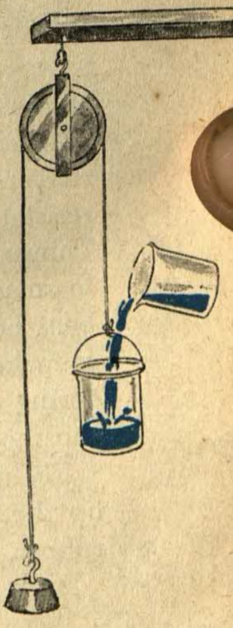
How do muscles work?

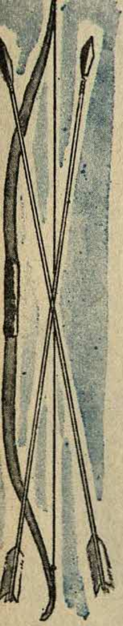
Lift a weight from the floor. In doing so you have done work. With the aid of your muscles, you have applied a force and moved the weight against the resistance due to gravity. Other examples of muscles doing work are to be found in walking, rowing, shoveling, lifting and so on.

It is estimated that human muscles do about one-sixth of the world's work. Fortunately, not all of the work must be done by human or animal labor. If it became necessary to do *all* of the work of the world with muscles, we should need the labor of eleven billion men. This is about five times the present human population of the earth.

How can objects that are lifted do work?

Try this experiment. Tie a small bucket to a string which passes over a pulley or roller. A weight slightly heav-





ier than the bucket is tied to the other end of the string. Now raise some water to the bucket and pour it in. Soon, enough water will have been poured in to raise the weight. When the water that you lift falls, it does work by lifting another body against the force of gravity. In the same way, water that is lifted by the sun's heat and then falls upon high ground becomes a fast-flowing river or a waterfall capable of doing work.

Man frequently makes use of the ability of a lifted weight to do work. The blow of a hammer makes the nail press apart the fibers of the wood and overcome the force of friction between the nail and the wood. In almost the same manner, the repeated blows of the huge weight of a pile driver, alternately lifted and dropped, may force steel pilings into the ground.

How can objects that are stretched do work?

Tie a rubber band to a small weight. Hold the weight on the table with one hand, and stretch the rubber band upward with the other. Release the weight so that the rubber band will pull the weight upward. Against what resistance did the stretched rubber band do work? Things that are bent, pulled or twisted so that they tend to snap back are ready to do work. For example, the bent bow can do work because it is able, if released, to make an arrow fly through the air. The coiled watch spring can do work because, as it slowly unwinds, it can move the wheels of a watch.

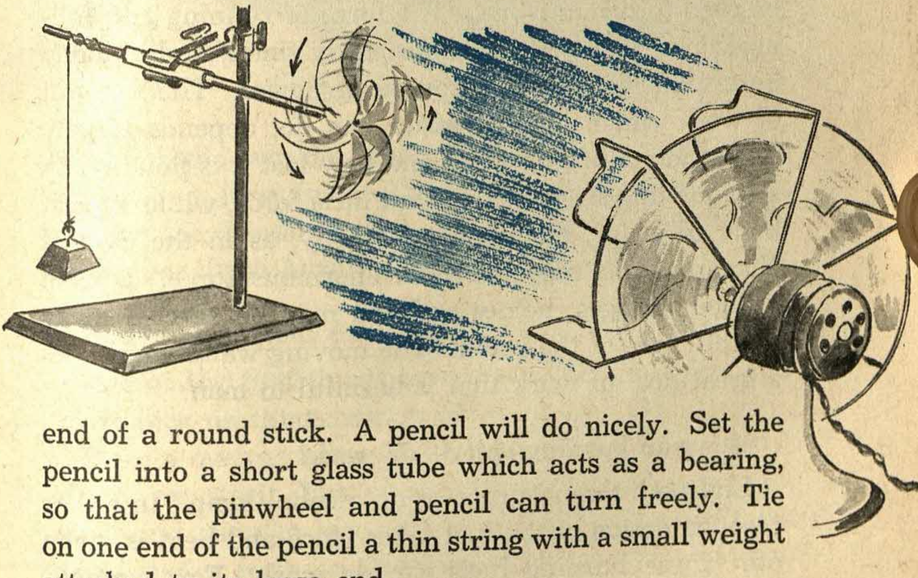
Fly a model airplane. Notice that when you wind up the rubber-band motor you stretch and twist the rubber. It is this stretch or twist in the rubber band

which can do work to lift the airplane from the ground.

How can moving objects do work?

By this time you are probably naming other forces which can overcome resistance. "What about the wind and water?" you ask. Let us experiment with them, for if we can make them lift a weight against the force of gravity, they are then capable of doing work.

Fold a pinwheel of paper and fasten it securely to the end of a round stick. A pencil will do nicely. Set the pencil into a short glass tube which acts as a bearing, so that the pinwheel and pencil can turn freely. Tie on one end of the pencil a thin string with a small weight attached to its loose end.



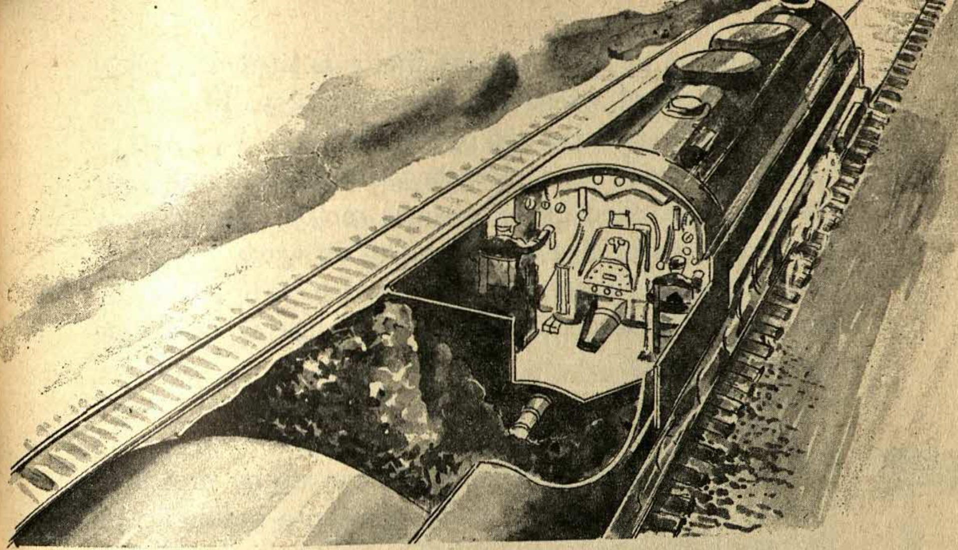
Notice that the pinwheel does not turn, even though it is surrounded by air. To make it turn, we must set the air near it in motion. Blow on the blades of the pinwheel. When the pinwheel turns, the string will wind around the pencil and lift the weight. From our experiment we see that wind, which is air in motion, can do work.

In lands where steady winds blow, people use windmills to do tasks which are usually performed by muscles. Farmers, for example, use the wind for pumping water, for grinding grain or for churning milk. In some instances the windmill is used to turn an electric generator that supplies the farm with electricity.

Just as air in motion can do work, water in motion can also overcome resistance. The flow of water may be used to turn a wheel. The force of running and falling water has been used since early times, and is today quite widely used as a source of power. The amount of work which moving water can do, depends largely upon the volume of water and how fast it is flowing. A slow-moving stream exerts but little force, while a great body of water, moving very swiftly, as in the case of Niagara Falls, may exert an enormous force. During a flood, bridges, homes and soil may be carried away by the force of the water. The moving water then does a great deal of work that is harmful to man.

How can burning objects do work?

Light a bunsen burner or an alcohol lamp. In either case, oxidation of the fuel takes place and heat is given off. These burning fuels can do work. For example, when water is boiled in a kettle covered with a tight-fitting cover, the cover is often lifted. As the water boils, steam is formed which pushes against the cover and lifts it. Thus work is done in lifting the cover and in overcoming the friction that holds the cover in place.



Much of the world's work is done by burning coal, oil, gas and other fuels. The steam engine, the gasoline engine, the Diesel engine, all can move objects because heat from burning fuels can do work.

How can magnets do work?

One of the first things one does with a magnet is to try to pick up things which are attracted to it.

Place a magnet a few inches above some small pieces of iron or steel. The pieces will immediately fly upward and cling to the ends of the magnet. Again we have used a force to overcome gravity—this time the force of magnetism.

How can an electric current do work?

Instead of using a windmill or water wheel to raise a weight, we may use any electric motor with a pulley or a spool on its shaft. As the motor is turned by electricity, the cord winds around the pulley, lifting the weight tied to the free end of the cord.

When you ride in an elevator you are lifted and your speed is controlled by an electric motor. As we may know, the use of electric current to do work has many advantages over other means. The ease with which one can control its force has multiplied its use in the home and in industry.

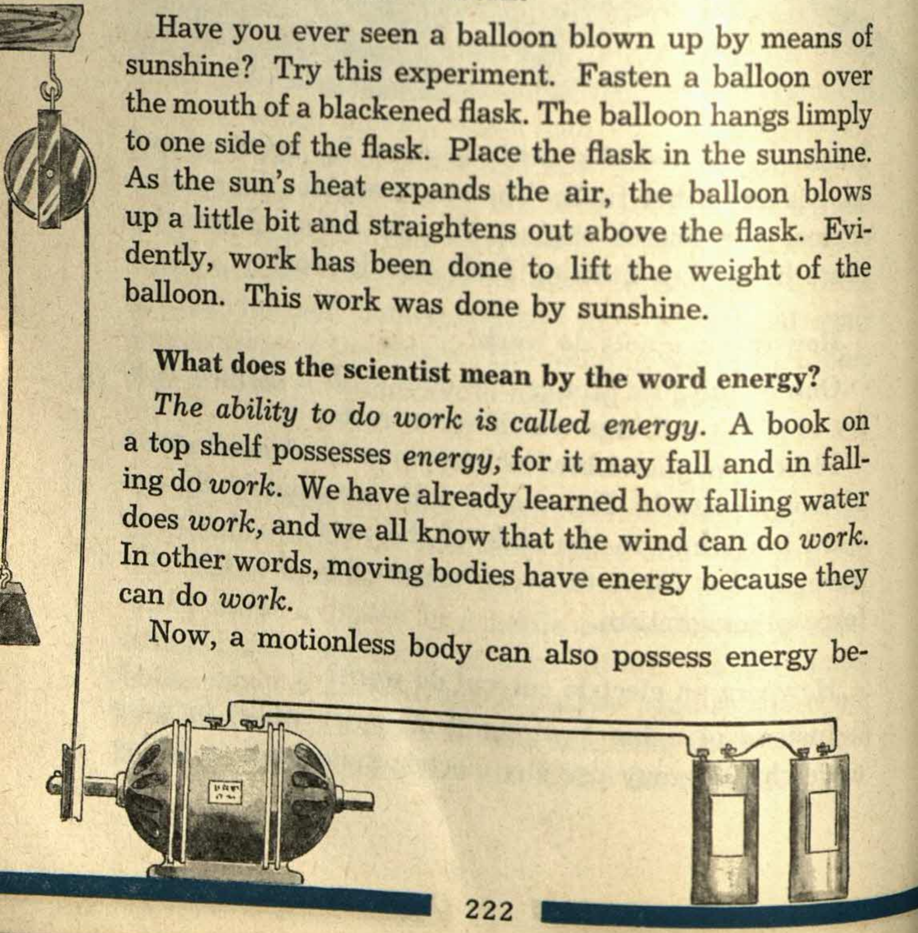
How can sunshine do work?

Have you ever seen a balloon blown up by means of sunshine? Try this experiment. Fasten a balloon over the mouth of a blackened flask. The balloon hangs limply to one side of the flask. Place the flask in the sunshine. As the sun's heat expands the air, the balloon blows up a little bit and straightens out above the flask. Evidently, work has been done to lift the weight of the balloon. This work was done by sunshine.

What does the scientist mean by the word energy?

The ability to do work is called energy. A book on a top shelf possesses *energy,* for it may fall and in falling do *work.* We have already learned how falling water does *work,* and we all know that the wind can do *work.* In other words, moving bodies have energy because they can do *work.*

Now, a motionless body can also possess energy be-



cause of its position or condition. A stone resting at the top of a hill has more energy than a similar stone at the bottom, for the former can be dislodged so as to roll down. Its elevated position gives it energy. Have you ever used a bow and arrow? Just before you let fly, you draw back the bow and aim. The arrow is perfectly still; the string and bow are stretched to the limit. There is energy in the bow, for it is able to do *work* when you release your hold. In this case the energy is due to the stretched condition of the bow. The same is true of a stretched rubber band or a wound-up clock spring. They possess energy even when motionless, for they are able to do *work* when released.

What are the different kinds of energy?

1. The wind whipped the ocean into a mad fury. Mountainous waves rose high above the tossing ship and smashed down upon it with terrific force. The steel decks trembled with each impact, and each attack of wind and wave brought the boat nearer to the dangerous shore. The heaving ocean lifted the ship and a second later the fearful crash of steel on rock could be heard above the howl of the wind.

. . .

2. In the railroad yards, Number Nine stood hissing and panting. Engineer and fireman were putting finishing touches on the machine which was to pull the Twentieth Century Limited on its long and rapid run. Under the boiler was a raging fire which consumed coal as fast as it could be thrown in. Heat, then more heat, was needed to boil water into steam, but the steam was not allowed

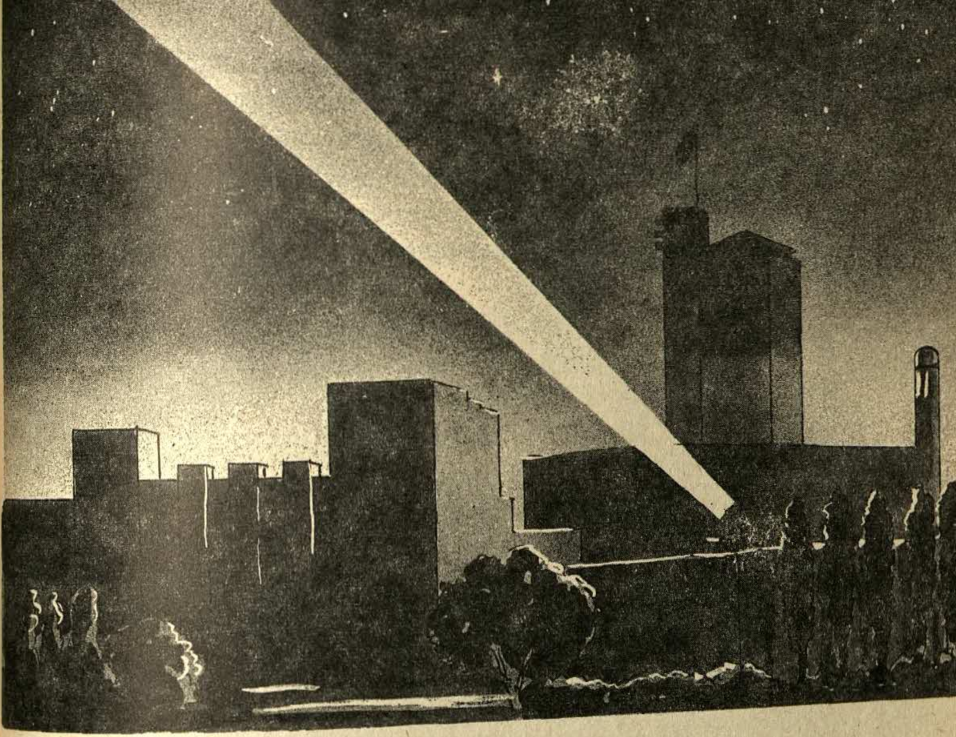
to escape. It crowded into the boiler and the pressure gauge climbed. Fifty! One hundred! Two hundred! The heat of the burning coal kept sending more and more steam into a vessel already filled. The locomotive did not move. It waited for a hand to operate a throttle.

. . . . .

3. Ten long cars of the subway train were opened for a rush of passengers who jammed their way into a space seemingly filled with people. The train was ready to start. One minute later the heavy steel cars, loaded with people, were speeding at fifty miles an hour. The turn of a lever had released energy for this task from an innocent-looking rail by the side of the track —the "third rail"—dangerous to touch, motionless, but charged with energy that could move tremendous masses at great speeds.

. . . .

4. Do you see this jar of liquid? It looks harmless, does it not? It is hard to believe that there is sufficient



energy in this liquid to bring the building down on top of us. This violent explosive is called *nitroglycerine.* It is a chemical, so unstable that heating it in a closed vessel will cause it to break up with terrific force. It stands there motionless and harmless, but in it are great stores of energy—energy that may kill and destroy. Yet, it can also be employed by man to do useful work.

. . . . .

5. In the year 1893 a World's Fair was held in Chicago. For untold ages the star Arcturus has been sending its light rays into space and speeding them on their way

to our earth. The rays which left this star in 1893 reached the earth forty years later (1933), after travelling 234 trillions of miles. For the first time in history, starlight was then put to work. The feeble energy obtained from Arctūrus was caught by a telescope and was used to switch on a searchlight which opened the Chicago World's Fair of 1933.

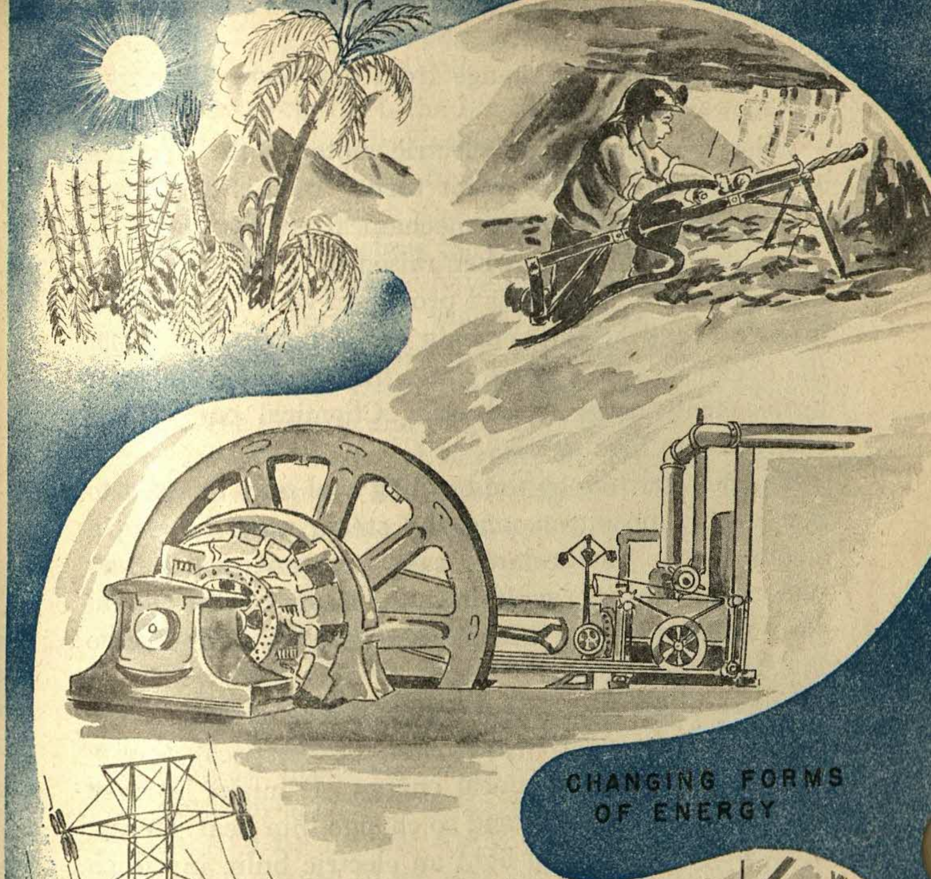
In each of the five paragraphs above, a different form of energy is described. If energy is the ability to do work, then there is energy in the waves, in the heated boiler, in the "third rail," in nitroglycerine and in starlight. But scientists have given different names to the forms of energy described in the different paragraphs. In the first we have *mechanical energy;* in the second, *heat energy;* in the third, *electrical energy;* in the fourth, *chemical energy;* and in the fifth, *light energy.*

How can energy change its form?

Lay a piece of lead on a hard board and pound it with a hammer. After a while touch the lead. Why did it get hot? It evidently possesses more heat energy than it did before the pounding. The scientist explains this by saying that the mechanical energy of the moving hammer changed into the heat energy of the lead.

We have seen that the cork will pop out of a test tube when the water in it is made to boil. Can we not say in this case that heat energy has changed into mechanical energy?

If a dynamo is to generate electricity, it must be turned. One must provide mechanical energy for turning in order to get electrical energy from the dynamo.



CHANGING FORMS OF ENERGY

Here, too, there is a change from one form of energy into another.

When you connect an electric motor with a source of electric current, the motor turns. In this case electrical energy changes into mechanical energy.

A piece of coal burns when raised to its kindling temperature in air. Burning is a process in which the carbon in the coal and oxygen in the air unite chemically. When the chemical action takes place, that is, when the coal burns, heat energy is released. Chemical energy has changed into heat energy.

The heat set free by the burning coal may be used to boil water into steam, and the steam may operate a steam engine. In the latter case, heat energy changes into mechanical energy. If, now, the steam engine should turn a dynamo, the mechanical energy would change into electrical energy.

The resulting electrical energy might be used to charge a storage battery, in which case the electrical energy would change into chemical energy. It might be used to heat an electric iron, and so change into heat energy. Or it might be used to light an electric bulb, in which case the electrical energy would be turned into light energy.

Thus, we have traced a series of energy changes. Chemical energy in a piece of coal changes into heat energy which, in turn, may change into mechanical energy. The latter may be changed into electrical energy which may itself be changed into chemical energy, into heat energy or into light energy. One form of energy may change or be changed into another.

Things to Do

1. Write a report on the life of Sir Isaac Newton and his scientific discoveries.
2. Prepare a bulletin board display of pictures and drawings which (a) show the disadvantages of friction, (b) show the uses of friction.
3. For centuries, there have been people who tried to invent perpetual motion machines. Once such devices are started they are supposed to run forever and do useful work. Find out about some of these devices and prepare a report for your class. Do you think such devices are possible? Why?
4. Make a trip to a hydroelectric power plant and learn how energy is changed into a more useful form.
5. Report to your class on the scientific discoveries of Archimedes.
6. Make a collection of common household tools and devices. Display them with labels to show which of the simple machines is illustrated in each.
7. Write an article for your school paper entitled, "What the world would be like without friction."
8. Write an article for your school paper entitled, "It would be a queer world without gravity."
9. Hold a contest to see who can make the longest list of examples of how gravity may do useful work.
10. Select a class committee to prepare demonstrations which illustrate centrifugal force.
11. Make a collection of materials used to reduce friction. We call these lubricants.
12. Prepare a bulletin-board display of large devices such as cranes and steam shovels. Locate and label each of the simple machines used in them.
13. Select a class committee to prepare demonstrations which illustrate inertia.
14. Build and operate a model of a windlass such as

is sometimes used to lift water from a deep well.

15. Build a model of a derrick such as is used in quarries or on ships for lifting heavy weights.

How Much Do I Remember?

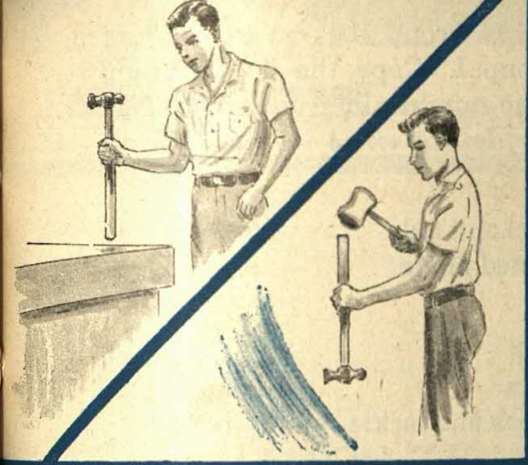
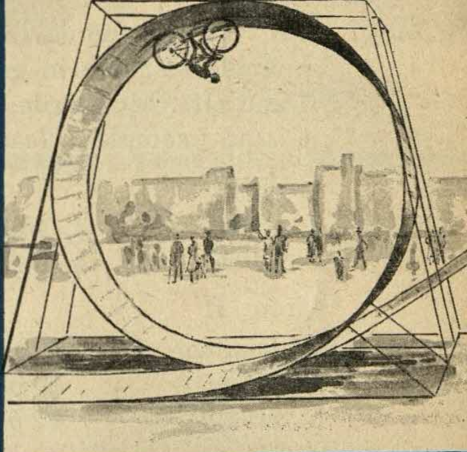
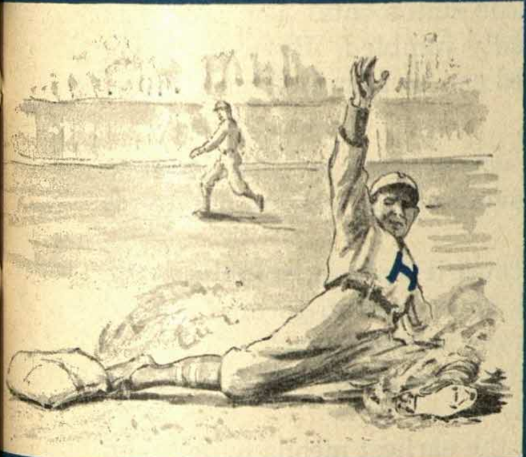
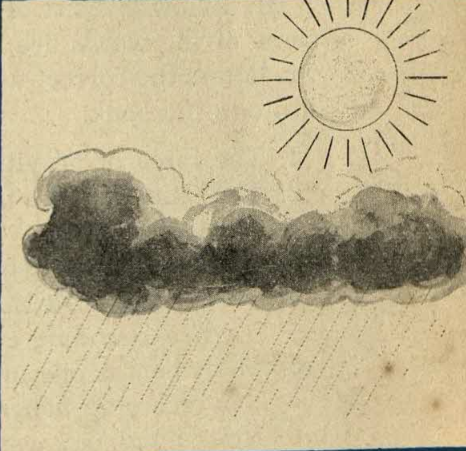
I. In group I are statements of important scientific principles. In group II are statements of various happenings. For each statement in group II find the statement or statements in group I which best account for the happening. *Please do not write in the book.*

Group I

1. All bodies in space attract each other.
2. The force of gravity depends upon the distance between two bodies.
3. Moving objects have a tendency to keep moving.
4. Friction is the resistance of one material moving over or through another.
5. The force of gravity between two objects depends upon their masses.
6. Objects at rest tend to stay at rest.

Group II

1. The moon continuously revolves about the sun.
2. A loaded truck must be started in first gear.
3. The flood waters swept away bridges and buildings.
4. An airplane flying high in the air weighs less than when it rests on the ground.
5. The boy gave a sudden pull on the rope and the box of groceries slipped off the sled.
6. After winning the hundred-yard dash, the sprinter kept going for several yards before he could stop.
7. Every year thousands of meteors plunge into the atmosphere of the earth.
8. The water in the ocean is humped up into tides.

I. Which one or more of the above drawings show an example of

1. Inertia of rest?
2. Kinetic energy?
3. Centrifugal force?
4. Heat energy?
5. Inertia of motion?
6. Friction?
7. The pull of gravity?
8. Energy change?
9. Mechanical energy?
10. Light energy?

Which drawings show an energy change from

1. Mechanical energy into heat energy?
2. Heat energy into mechanical energy?
3. Chemical energy into mechanical energy?

II. Each of the devices in group II is an example of a simple machine in group I. Copy the list in group II and after each write the number in group I of which it is an example. *Please do not write in the book.*

Group I

1. pulley
2. lever
3. wheel and axle
4. inclined plane
5. screw
6. wedge

Group II

A. hammer
B. chisel
C. scissors
D. bolt
E. oars
F. block and tackle
G. grindstone
H. auger bit
I. knife

III. Below is a list of true statements. The letters in some of the words are badly jumbled. By rearranging the letters the correct word can be found. *Please do not write in the book.*

1. The force of gravity was studied by *caisa wonten.*
2. The tendency of a moving object to keep moving is called *atrinie.*
3. A thing has *thewig* because it is attracted to the earth.
4. *Crufageltin crofe* may cause cars to go off the road when rounding curves at high speed.
5. The wheel is one of the most important devices for overcoming *fioncrit.*
6. *Hamun culmess* were the earliest means which men had for moving things.
7. *Pleims chinames* are useful in doing work.
8. The weight lifted by a lever is called the *tressnaice.*
9. A force can be multiplied by using a *valbome lulepy.*
10. Roads which pass up hills are *cinnidel snapel.*
11. The ability to do work is called *greeny.*
12. *Nungrin tarwe* can do work.
13. *Gemnats* are useful devices for doing work.
14. *Citcitreely* is a widely used form of energy.
15. Ocean waves possess *maniaclech negrey.*

ENERGY FOR TRANSPORTATION

INSTITUTE OF EDUCATION FOR WOMEN
Dept. of Extension
SERVICE.
CALCUTTA-27

Moving Things from Place to Place

3700 B.C.

Not far from Cairo, Egypt, on the edge of the vast desert, stands a tomb built to shelter the body of a noted Egyptian ruler. It is the Great Pyramid of Khufu, which for over five thousand years has excited the curiosity and wonder of thousands of persons who have seen it. When first built, the huge structure was 756 feet square at the base and 482 feet high. It is made of about 2,300,000 blocks of stone which take up a space of nearly 3,400,000 cubic yards.

The famous Greek historian, Herodotus, reported that 100,000 men labored 20 years to build the Great Pyramid. If we were able to look back through the centuries and see the pyramid under construction, we should see thousands of workmen splitting huge blocks of stone in quarries, using only the crudest tools. Dragging the blocks would be more thousands, driven like animals by the whips of overseers. Up long slopes, the blocks would be moved to their proper positions in the structure. Human muscles and simple tools built the Great Pyramid, which was the monument and tomb of a king.

1935 A.D.

Stretching between the walls of Black Canyon on the Colorado River is a structure known as Hoover Dam, or Boulder Dam. The Congress of the United States voted $165,000,000 in 1928 to build a dam which would control floods, develop water power and provide water for irrigation and domestic use. This dam is 650 feet thick at its base and 45 feet thick at the top. It is 726 feet high. In making it, 4,200,000 cubic yards of concrete were used—almost a quarter more than the amount of stone in the Great Pyramid.

A few hundred men, at most a very few thousand, made this mighty structure in less than seven years. With chattering drills they quickly sank holes in the rock and loosened great masses of it by blasts of explosives. Chunks of stone crumbled to pebbles between the jaws of crushing machines. Twenty-five tons of rock were carried by trucks in one load. Large steel buckets of concrete were swung to the desired place by the arms of derricks. A few men sitting before levers and wheels and valves controlled the movement of the great mass of material used in the dam. Human muscles merely controlled the forces of steam, electricity and exploding gasoline in building a structure which is now of service to many thousands of people.

What resistances must be overcome in order to move anything?

In our study of pushes and pulls, we learned that the weight of an object is due to the pull of the earth upon it. When we lift it, we overcome the resistance due to the gravity of the earth. We must exert a force equal to the weight of the object being lifted.

In sliding an object two resistances must be overcome. First, there is a resistance due to rubbing against the surface on which the object moves. This we have called friction. As we now know, the heavier the object, the greater is the friction. Also, the smoother the surfaces in contact, the smaller is the friction.

The second resistance which must be overcome, if the object is to slide, is the resistance due to inertia. Even if the object were resting on the most perfectly polished surface and on frictionless wheels, a push or a pull would still be needed to start it moving.

Usually, it requires less force to overcome friction and inertia than it does to overcome gravity. Hence, we would often rather slide a heavy box than lift it. Of course, it is sometimes necessary or convenient to lift things rather than slide them. No matter what method we use to move anything, we must always exert a force to overcome either gravity and inertia, or friction and inertia, or all three resistances.

How do animals overcome resistances?

Most animals can move about freely. Whenever they do this, they are overcoming resistances. When a squirrel climbs a tree, it overcomes the force of gravity of the earth upon its own body. When a snake glides through the grass, it overcomes the friction of its body's rubbing against the earth and the grass. When an animal starts to run, it must overcome the inertia of its own body.

Animals can move because their bodies have muscles. The bundles of cells we call muscles are especially adapted for changing their lengths. When they do this, they exert a pull. The muscles of animals can usually exert much more pull than needed to move their own bodies. Hence, they can also move other things. Many animals can carry quite heavy weights in their mouths. If you have ever watched ants at work, you may have seen an ant dragging the body of some insect much bigger than itself. In digging their burrows woodchucks and prairie dogs gradually move large amounts of earth.

Thousands of years ago, men learned that animals had muscles strong enough to move heavy objects. Dogs, camels, elephants, horses and a few other animals have long been used to carry things or pull things. Harnesses are made so that animals can be used to drag objects

heavier than the ones they can carry on their backs.

How does man overcome resistances?

Man possesses muscles just as other animals do. However, he has one possession which is much better than that of any animal. He has hands. You will notice that your hand is like a pair of tongs or pliers. The thumb is one part of the tongs and the fingers the other. No animal has feet which are as good for grasping things as is the human hand. For this reason, man can lift and push things much more easily than can animals.

All of us must move things as we go about our daily duties. We carry books and travelling bags, bundles of groceries and buckets of water. We push brooms and baby carriages, flatirons and pencils. Every day we are constantly using our muscles to move things.

Man differs from animals in another way. He has a more highly developed brain. He is not satisfied merely to get enough to eat, to keep warm and to protect himself. He likes to build things that are so big that the materials needed cannot be moved by his muscles alone. Long ago he learned to use animals to help him. He also tried to make other people his slaves, forcing them to use their muscles to do his work. Nowadays we employ people who are specially skillful to do various kinds of work for us.

Using his fine brain, man has found ways of moving things without using either the muscles of human beings or of animals. A very large part of the moving needed in the civilized parts of the world is done by means of forces which do not come from living things.

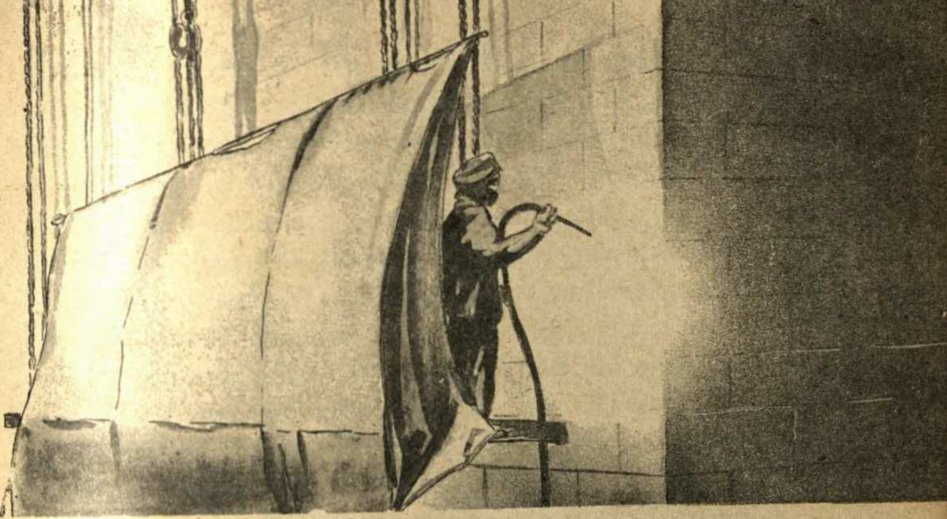
How can flowing air be used to move objects?

No doubt man noticed long ago that the wind could move things. He saw dust and leaves swirling through the air. He saw leaves and branches of trees swaying in the wind. In storms, branches were torn from trees, and sometimes the trees were uprooted. He saw waves driven by the wind, crashing against the shore, washing away the soil and even rolling large stones about. He felt the wind push against his body.

Sometime in the past, people learned that floating objects were driven over the water by the wind. By spreading a broad surface to the wind, the push could be increased. Sails were thus invented, and even today they are used for moving boats, although they are not so important as they were a hundred years ago.

As we learned in the last chapter, moving air can be used to turn wheels. There are many kinds of windmills. In this country they are used on some farms to pump water and to supply electricity for charging batteries. In Holland, they are used to do all kinds of work. Recently in this country, a very large windmill was constructed on a mountain where the wind is always strong. This windmill was planned to provide electricity for a whole town. Possibly, we shall see more such windmills in the future.

Moving air is sometimes used to drive sand with great force against stone and brick buildings in order to clean them. Such a device is called a sandblast. The common vacuum cleaner uses moving air to push the particles of dirt out of rugs and carpets.



How can flowing water be used to move objects?

We have all seen how flowing water moves objects. We have learned how to use flowing water to do useful things. Logs are often cut far from the mills where they are made into paper, lumber and other things. It is common to float the logs on rivers which carry them to the mills. In case a river is not located near the logs, big troughs, called flumes, are sometimes built so that the logs can be floated.

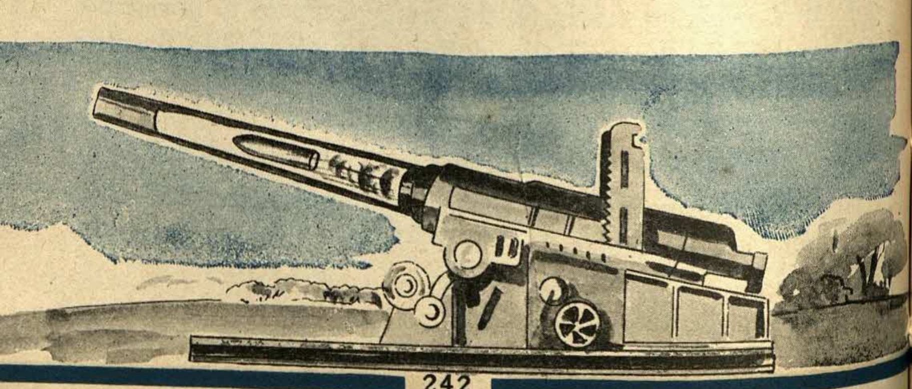
When we use a hose to wash an automobile, we are making use of flowing water to carry away dirt particles. In a washing machine, the water is made to flow back and forth through the clothing, thus washing out the dirt caught in the fibers.

How can burning fuels be used to move objects?

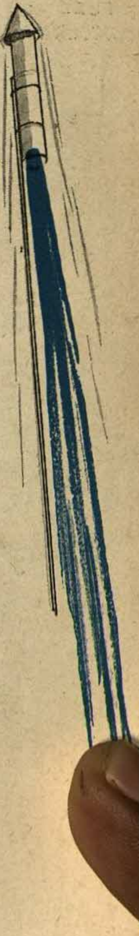
Whenever fuels burn, heat is produced. As we know, heat causes molecules of a heated substance to move more rapidly. In addition, gases are produced when fuels burn, even when the fuels themselves are solids or liquids. Hot gases tend to expand, so they can be used to move things.

The most violent movements are caused by fuels which burn very rapidly. Usually we call such materials explosives rather than fuels. When a gun is fired, whether it is a .22 caliber rifle or a giant sixteen-inch cannon, the bullet is pushed out of the gun barrel by the hot gases which are formed when powder burns very quickly. The cannon may throw a projectile weighing a ton more than twenty miles and at a speed of more than two thousand feet per second. Certainly this is moving an object in a terrific manner.

In a gun, the push needed to move the bullet is made by burning the powder in a narrow space between the closed end of the gun barrel and the bullet. The push acts on the bullet only while it is moving along the gun barrel. Another way of pushing an object is to attach the fuel to the end of the object. If the fuel burns rapidly, the stream of gases flying out one end of the object pushes it in the opposite direction. This is the way a rocket works. Since the fuel is carried along by the object, the push lasts until the fuel is completely

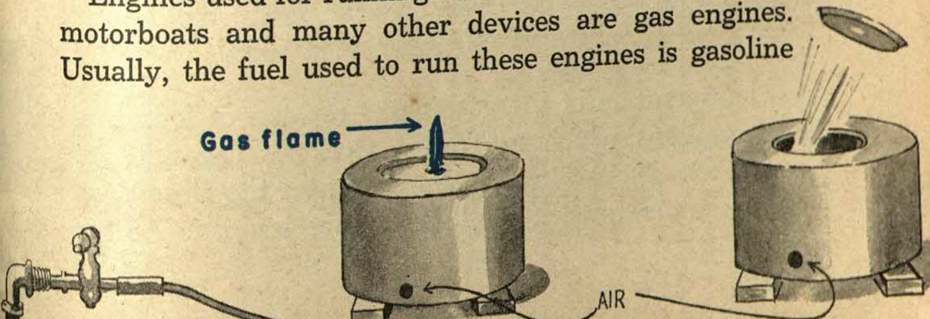


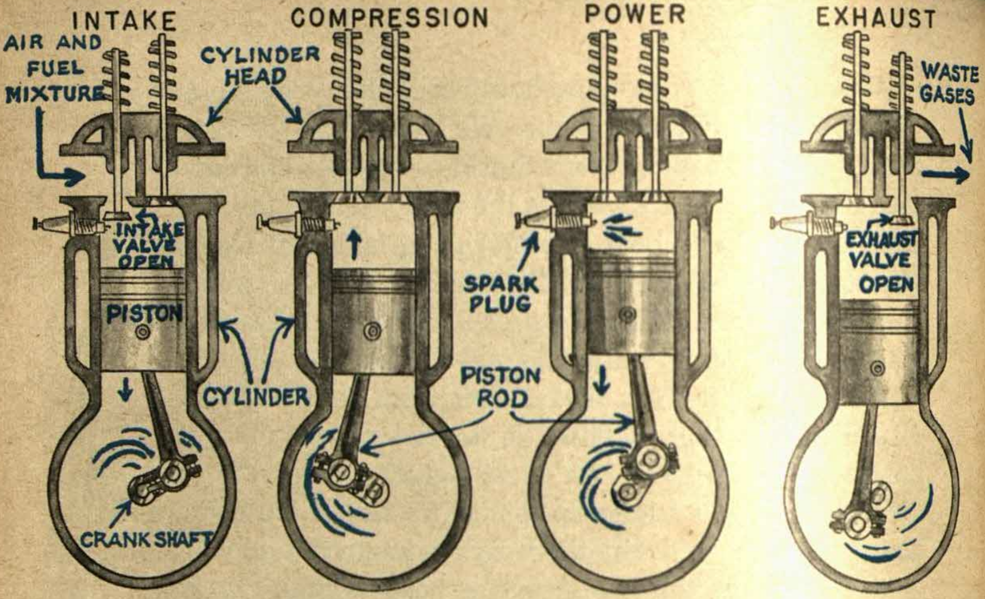
used up. All of us have probably seen the rockets used in Fourth of July celebrations. We have heard the swish of the gases escaping from the burning fuel and have seen the trail of sparks left as the rocket soared upward. Recently we have heard of "jet propulsion" airplanes. The new jet-propelled airplanes move without propellers. As a powerful jet of gases leaves the plane, the plane is pushed forward at great speed.



The gas engine is a device which uses burning fuels to produce motion. Let us do an experiment to learn how burning fuel gas can exert a push. Prepare a tin can fitted with a friction cover as shown in the drawing. Make the hole in the cover one-quarter inch in diameter. Make the hole near the bottom large enough so that the rubber tube can be inserted into it. Insert the tube from the gas jet into the hole. Turn on the gas. Light the gas issuing from the hole in the cover. Turn off the gas jet and withdraw the tube from the hole. Now stand back and watch closely. The flame at the top grows smaller. Air enters at the bottom to form a mixture of gas and air inside the can. Suddenly there is a pop and the cover flies off. This was caused by rapid burning, or explosion, inside the can. The heated gases expanded and pushed off the cover.

Engines used for running automobiles, busses, trucks, motorboats and many other devices are gas engines. Usually, the fuel used to run these engines is gasoline





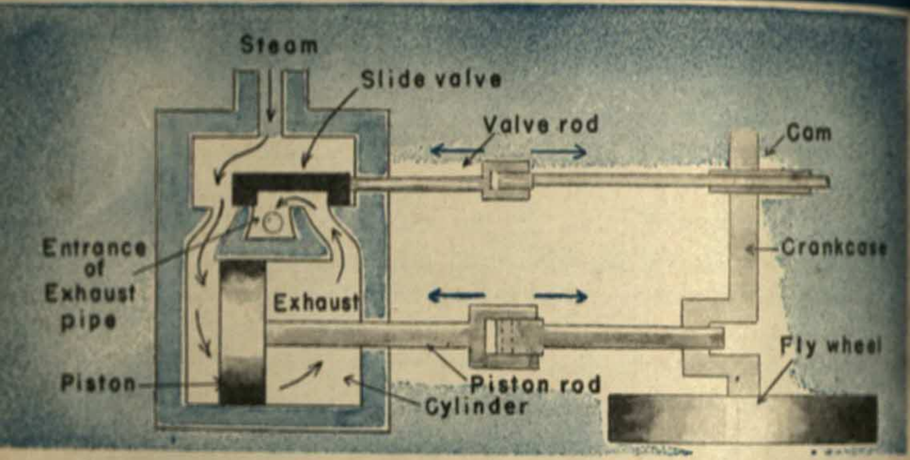
Four strokes of the piston in the cylinder of a gas engine.

—a liquid. Before the gasoline is used in such an engine, it is evaporated and mixed with air in a device called a carburetor. Thus the fuel is in gaseous form when it enters the engine.

Let us study the way a gas engine works by the use of the diagram at the top of this page. In gas engines, there are one or more cylinders. Each cylinder contains a piston which can slide back and forth. The piston is connected to a crankshaft by a piston rod. As the piston moves, the crankshaft turns. At the closed end of the cylinder, there are two openings which may be closed or opened by valves.

The operation of the gas engine consists of four separate actions which are called strokes. The first, or *intake stroke,* starts with the piston near the closed end of the cylinder when the intake valve is open. As the piston moves toward the open end of the cylinder, a partial vacuum is formed above it. A mixture of gasoline vapor and air rushes in from the carburetor through the open intake valve. In the second, or *compression stroke,* both valves are closed and the piston moves toward the closed end of the cylinder. The mixture of gasoline vapor is compressed into a small space. The third stroke begins just as the piston starts toward the open end of the cylinder again. At this instant, an electric spark is produced at the spark plug. This sets fire to the gasoline vapor which burns very rapidly. The hot gases thus produced expand to push the piston toward the open end of the cylinder with great force. That is why the third stroke is called the *power* stroke. As the piston is pushed outward, the crankshaft is turned rapidly. In the fourth, or *exhaust* stroke, the piston again moves toward the closed end of the cylinder. The waste gases are pushed out through the exhaust valve, which now opens. Then the whole process starts over again with an intake stroke.

It is only during the power stroke that the burning fuel pushes against the piston to make it move. That is why a gas engine must be started either with an electric motor, as in the starter of an automobile, or by cranking by hand. When a cord is pulled on an outboard motor or a lawn mower motor, the crankshaft is turned and the piston made to move through the intake and compression strokes. After the power stroke, the rapid turning flywheel on the motor keeps the piston going through the exhaust, intake and compression strokes to the next power stroke. Many gas engines have several



cylinders all connected to the same crankshaft. By proper timing of the spark, the power stroke occurs in one cylinder at a time. This makes for a more smoothly running engine. In each cylinder, the valves open and close at the proper time. The sequence of action in the cylinder is controlled by the motion of the crankshaft.

At the top of this page there is a diagram of one type of steam engine. The steam is produced in a boiler and brought to the engine through a pipe. The steam has high pressure. When it enters the cylinder, it pushes the piston toward the opposite end. Then the valve moves so that steam enters on the opposite side of the piston to push it back again. The steam already in the cylinder is allowed to escape through the exhaust pipe. In the steam engine, the steam pushes the piston first in one direction and then in the other, so that each stroke is a power stroke. Hence, there is no need for several cylinders. The moving piston turns a crankshaft which in turn opens and closes the valve at the proper time.

Across the Land

A map of Western Canada and Alaska shows that this is a region of high mountains with few towns, roads or railroads. Great forests cover the valleys and hillsides. The rivers flow swiftly over rocky beds. In some places there are great bogs filled with masses of water-soaked moss and mud which shake like jelly when one walks over them. Many parts of this wilderness have not been well mapped; some parts have never been seen except by Indians and trappers.

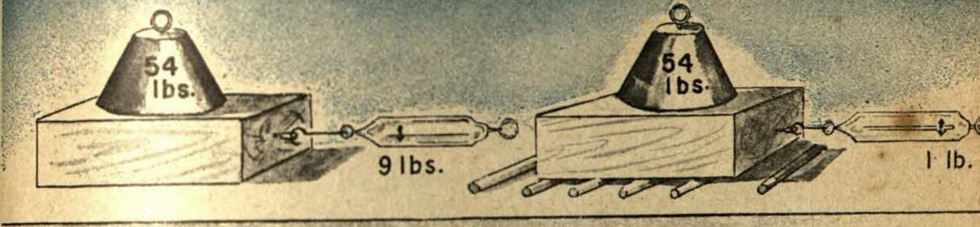
When war with Japan started in December, 1941, it became necessary to build a highway over which men and supplies could be carried to defend Alaska. It had to be built through this region of forests and mountains, of swamps and rivers, and it had to be built quickly. The United States Army Engineers were assigned to build the road.

Giant tractors were used to tear a pathway through the forests. Layers of tree trunks were laid over the swamps to support the weight of vehicles and men. Trucks floundered through mud knee deep, bringing supplies for the engineers and materials for building the road. Pontoon bridges were thrown across wide rivers. Axes and spades, ditching machines and Diesel shovels, horses and jeeps, river boats and airplanes, all played their part in building the Alaska Highway, 1671 miles long.

Secretary of War Henry L. Stimson described the achievement in these words: "Ten thousand soldiers, divided into seven Army engineer regiments, and 6000 civilian workmen under direction of the Public Roads Administration, completed the job in slightly over six months. They pushed forward at the rate of eight miles a day, bridged 200 streams, laid a roadway 24 feet wide between ditches, and at the highest point, between Fort Nelson and Watson Lake, reached an altitude of 4212 feet."

Why is the wheel called man's most important invention?

Centuries ago men learned that heavy loads could be dragged more easily by placing them on sleds or sledges with smooth runners. Even today we see these in use. A pair of horses cannot drag a very large stone along the ground since the rough edges dig furrows, thus increasing the friction. Much larger stones can be hauled on smooth sledges, but, at best, there is always friction between the ground and even the smoothest object.


54 lbs.
9 lbs.
54 lbs.
1 lb.

Transportation of heavy objects on land did not become easy until the wheel was invented. As we know, a wheel is a disk with a hole in its center through which is inserted a round shaft, or axle. When wheels are fitted under a sledge, we have a wagon. The sliding friction of the sledge is thus changed to rolling friction.

Let us see how wheels can reduce friction. Place a heavy box on the table. Attach a spring scale to it and pull it along, noting the reading of the scale. Now rest the box on rollers. Round pencils will do nicely. They will serve as wheels although they are not attached to the box. Note the reading of the spring scale as you pull the box over the rollers. Do you find that more force is needed or less?

No invention is of greater importance than the wheel, for it has made modern land transportation possible. Not only is the wheel used to reduce friction between the ground and moving vehicles, but it is also used in countless ways as parts of machinery for doing the work of the world.

How is friction overcome in vehicles?

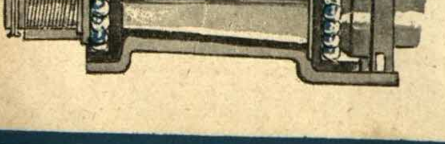
We have seen that a push or pull is needed to move objects along a level surface, only because friction and inertia must be overcome. Anything that helps cut down friction makes easier the task of moving things. The wheel reduces friction but does not eliminate all of it. The hub of the wheel still rubs on the axle. By making the hub and axle of metals which are hard and smooth, friction is reduced. Add oil or grease, and the friction is reduced still more.

The moving parts of machines are always lubricated to make them run more easily and to prevent too rapid wear. Whenever two surfaces rub together, tiny bits of each are torn away. A good deal of heat is produced, too. Oil and grease keep the surfaces separated by a thin film which reduces wear, friction and heating.

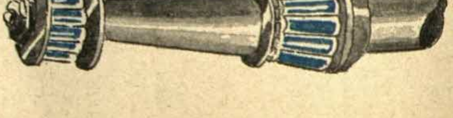
In many machines the sliding friction of a wheel on its axle is changed to rolling friction by inserting between the two a layer of steel balls or rolls. Such an arrangement is called a ball or roller bearing. The balls and rollers are kept lubricated. Automobile and bicycle wheels turn on ball bearings. The friction is reduced so much that a vigorous push will cause a bicycle wheel to spin for a minute or more.

Any well constructed and properly lubricated vehicle has little friction in its wheels or other moving parts. There is always some friction, however, between the wheels and the surface over which the vehicle is moved.

Ball Bearings



Roller Bearings

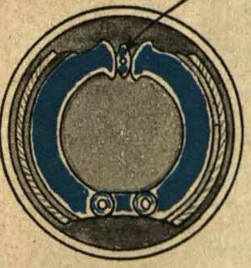


On very rough ground, the wheels drop into the hollows so that they must be lifted out of them as the vehicle moves along. Sometimes farm carts and tractors are provided with large wheels that run over the tops of the smaller hollows. Where vehicles are regularly used, smooth roads are built. Originally roads were merely paths made by smoothing the soil. Dirt roads of this kind become muddy in wet weather and the wheels sink into them, increasing the friction. The small wheels of automobiles may sink so deeply that the car cannot move. Modern highways have a hard surface of concrete or of stone mixed with tar. These roads are not much affected by the weather. Wheels do not cut into them.

How does friction make travel safer?

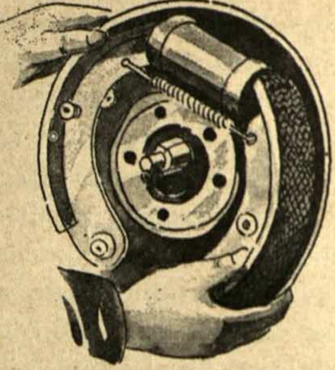
This world would be a very strange place without friction. If there were no friction, the wheels of automobiles and locomotives would spin without causing any forward motion. It is necessary then that roads be rough enough so that automobile tires can grip them firmly when the automobile is stopped. The ridges on a tire are designed to create the proper amount of friction on the road.

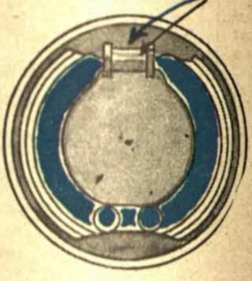
Without friction, a body in motion would continue to move forever. A wind once started would blow forever. Without friction, ocean waves would never die down; the sea would never grow calm. On modern highways a rapidly moving car will coast a long distance before friction brings it to a stop. In order to stop vehicles quickly, brakes are necessary. Friction is de-



Cam pushes brake shoes apart

Mechanical brakes





Oil pressure pushes brake shoes apart

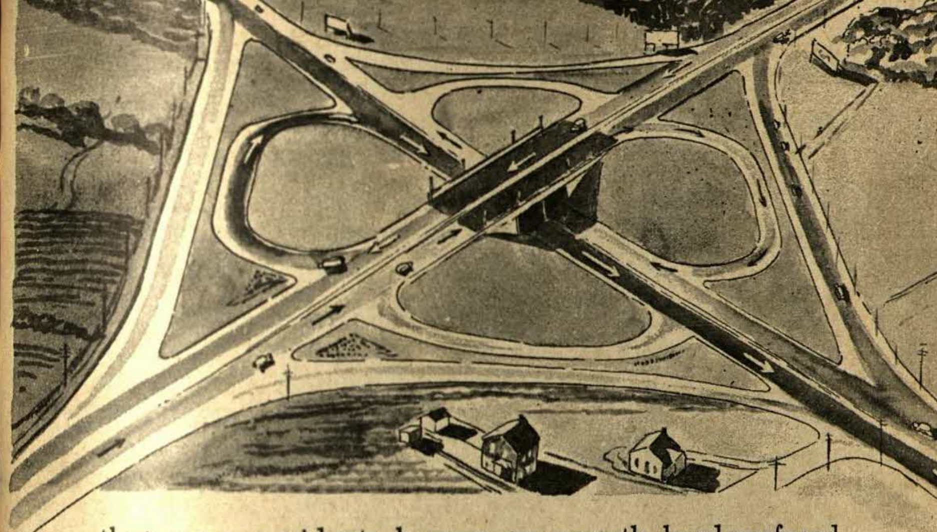
Hydraulic brakes

veloped by pressing the two parts of the brakes together.

On railway cars, the brakes are pieces of iron curved to fit the outside of the steel wheels of the car. When the brakes are applied, the friction is often so great that sparks fly from the wheels. In automobiles, bands of tough material are pressed against the inside or the outside of a metal drum on each wheel. The bands commonly contain some asbestos, which does not catch fire.

When is a highway safe for travel?

While fine highways have made easy the movement of goods and people, they have also made possible high and sometimes dangerous speeds. Pleasure cars, loaded busses and trucks carrying tons of freight, often travel at speeds of fifty or more miles per hour on the same highways. Vehicles travelling at high speeds have much inertia of motion. They cannot be stopped suddenly, even with the best brakes. Consequently, highway accidents have become very common. A careful study shows



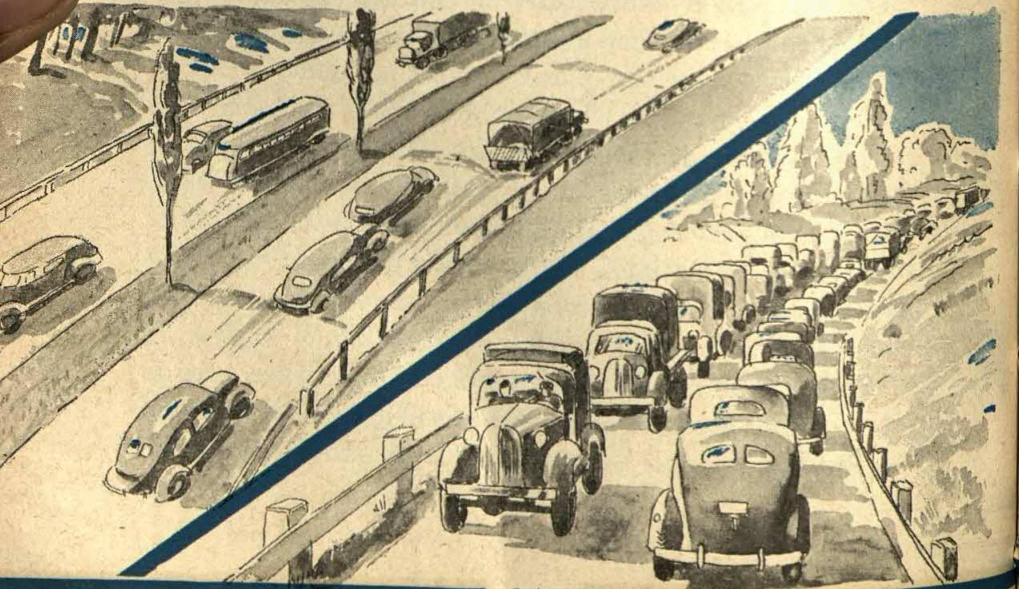
that more accidents happen on smooth hard-surfaced roads than on poorer roads, since such roads carry more and faster traffic.

For several years, about forty thousand persons have been killed and over a million injured yearly in automobile accidents. This means that, on the average, one person is killed every thirteen minutes and two persons are injured every minute. Highway engineers have studied carefully the places where accidents occur in order to find ways in which to build roads that are safer. A great many accidents happen at the intersections of roads and at railroad crossings. On the newest highways, bridges carry traffic over railroads and other highways. Sometimes traffic circles or cloverleaf intersections are installed to make it unnecessary for one line of traffic to cross another.

Every year many accidents occur on curves and on steep hills. Modern highways are made as straight and as level as possible. Often houses are moved to permit roads to be built more nearly straight. Hills are cut away and hollows are filled in to make the roads level. Signs are set along roadsides to warn drivers of steep hills, curves and side streets that are ahead.

Roads built some years ago were wide enough for only two lines of traffic. Such roads are dangerous where the traffic is heavy, because it is necessary for a car to swing out into the line of oncoming traffic in order to pass another vehicle. To prevent this danger, many highways are now built as two separate roads with a space between. All the traffic in each road travels in the same direction. In roads where lines of traffic in opposite directions cannot be separated, a broad white or yellow band is painted in the center. Cars are expected to stay on the right-hand side of this line.

No matter how carefully a road is planned it may become dangerous for travel under some conditions of



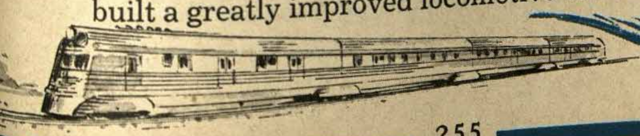
weather. Heavy rains tend to make roads slippery. Snow and sleet are much worse because they decrease the friction so much that cars cannot be steered properly nor stopped quickly. The use of sand on icy roads increases the friction and makes them safer.

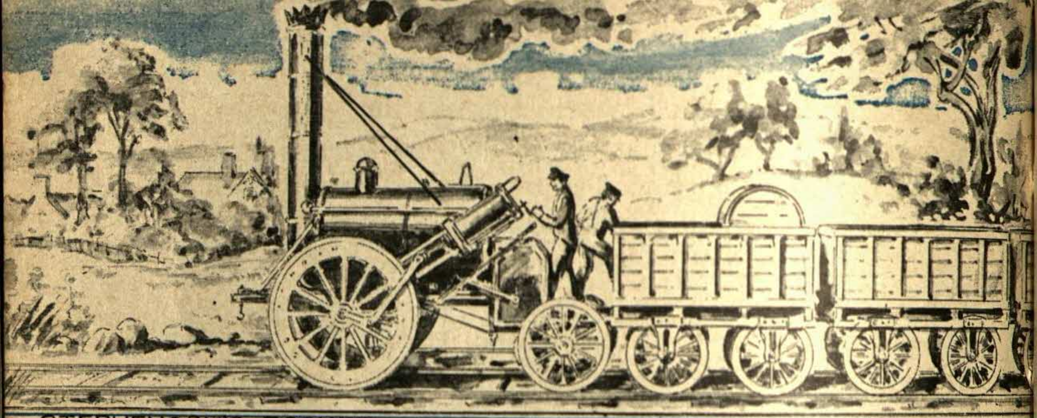
Accidents still occur even on the best highways. Usually such accidents are due to the carelessness of drivers who go too fast or fail to observe the signs warning them of danger. Drivers who do not keep their brakes in good order cannot stop in time. When worn or damaged tires are used, a blowout may result, causing the car to swerve into other cars or off the road. Occasionally an accident is caused by the breaking of some part of the car. That is not common in modern cars because the metals and other materials used in constructing them have been greatly improved and strengthened as a result of careful scientific study.

How have the automobile and the locomotive changed our lives?

A hundred and fifty years ago, travel by land was very slow. People walked, rode horses or used wagons. Roads were few and poor. At best, only a few miles could be covered in a day.

When the modern type of steam engine was invented in 1769, people began to dream of harnessing it to a wagon which would travel faster and carry heavier loads than horse-drawn vehicles. Many experiments were made, but the first successful locomotive did not appear until 1804. Stephenson, an English engineer, built a greatly improved locomotive in 1829. In the same





STEPHENSON'S ROCKET

year the first locomotive was used in the United States.

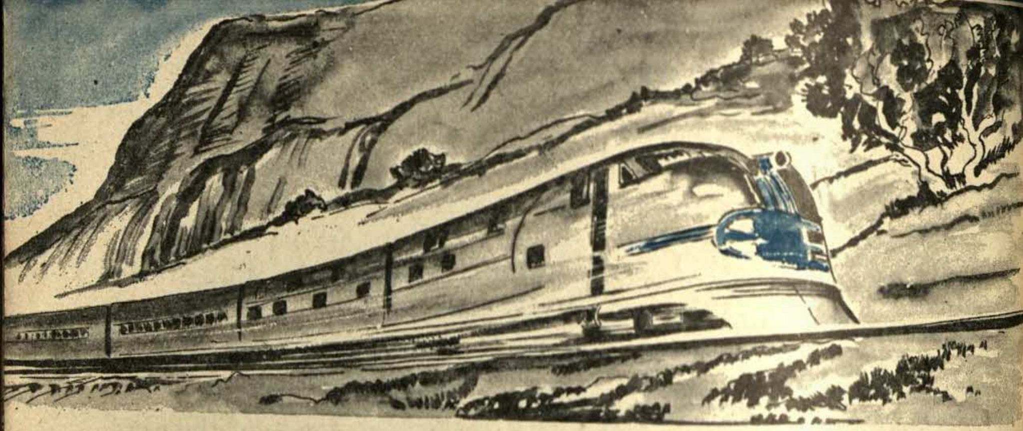
The great weight of steam engines made locomotives too heavy to travel on dirt roads. Consequently, they were built to run on tracks which came to be known as railroads. It was soon found that locomotives could be built powerful enough to draw many cars upon which tons of weight could be carried. In the last hundred years railroads have been built in all parts of the country. Locomotives have been made bigger and more powerful. Both freight and passenger cars have been increased in size and in their ability to carry larger loads.

Until railroads were constructed, it was almost impossible for people living far from the seashore and rivers to get things from other places. The cost of carrying goods on horseback or in carts over the poor roads was so great that only the most necessary things could be transported. Travel was so slow and uncomfortable that few people ever went more than a few miles from home. Goods were not manufactured because the cost of sending them to market was too great. Because of these conditions, the greater number of the people lived near the seacoast or along large rivers where trade and travel could be carried on by boat. People living inland were forced to live apart from other people. They had to raise their own food and make their own clothing.

The railroads changed all this. They brought to many more people the benefit of goods from distant places. They made it possible for everyone to travel more widely and to meet other people. The great farm lands of the West were developed because grain and cattle could be shipped to Eastern markets. Cities and their factories could be located almost anywhere, because the railroads could bring in raw materials and take away manufactured products. The railroads have done a great deal to bring certain advantages to all, which only a few were once able to enjoy.

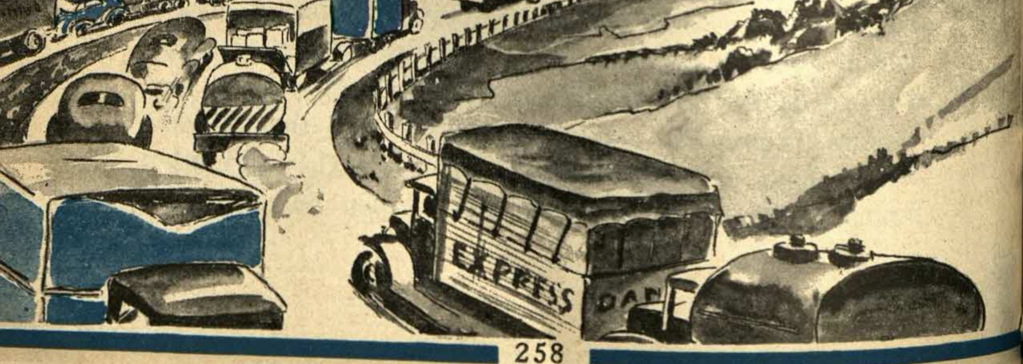
Of course, railroads cannot reach all the small towns and the farms because it costs a great deal to build and maintain them. In some parts of the country, one must travel many miles to reach a railroad. In 1860 the gasoline engine which burned fuel in the cylinder was invented. It was no longer necessary to have a heavy boiler for making steam. This lightweight engine was just the thing needed to drive vehicles designed for travelling over highways rather than on rails. A great deal of experimenting finally produced the comfortable and speedy automobile of today.

There is scarcely any populated place in the United States that automobiles cannot reach quickly. People living on farms and in small villages can now have a



variety of food and clothing not possible before. People can travel quickly to places of entertainment. Farm products can be delivered rapidly to markets. The automobile makes it possible for workers in cities to travel easily to homes in the country.

The automobile and the railroad together make it possible for us to have things that come from many places. They make it possible for us to travel widely and quickly.



Over the Water

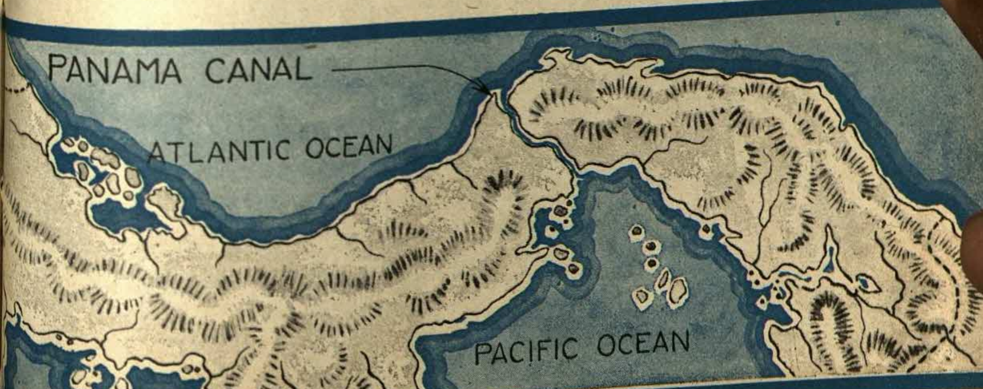
"We have just completed a number of experiments showing how boats can travel over water. We are going to have a special treat today. John is giving us a talk entitled, 'Going East from the Atlantic to the Pacific.' "

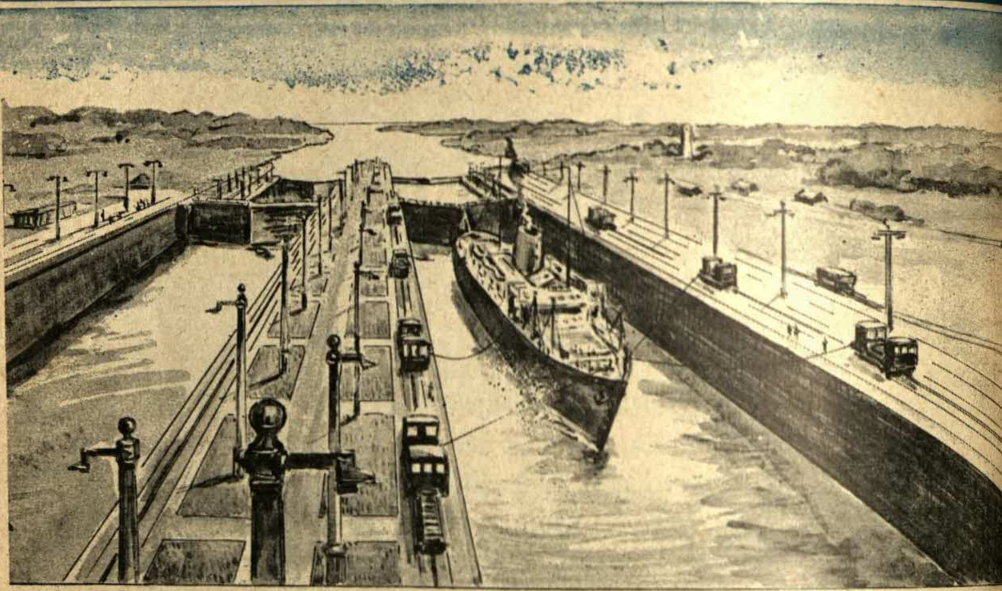
John walked to the front of the room and addressed his classmates.

"Last July, my father was transferred from New York to San Francisco. Our family decided to make the trip by boat. We saw many interesting things on the way, but I think the Panama Canal was the most marvelous.

"If you will look at this map you will see that only a narrow strip of land, called the Isthmus of Panama, connects North and South America at this point. Also, you will notice that the Isthmus runs in an east-west direction so that the Gulf of Panama in the Pacific Ocean is actually east of the Atlantic Ocean at this point, which is called the Gulf of Mosquitoes. So the Pacific end of the Canal is east of the Atlantic end.

"In 1881, a French company started to build a canal but they did not complete it. One of the reasons was the great number of mosquitoes which spread the dis-





eases, yellow fever and malaria. In 1904, the United States secured the rights to build a canal. Three years were spent in eliminating mosquitoes and providing good places for workmen to live. The canal was completed in 1914.

"The canal is about forty miles long, not less than three hundred feet wide and at least forty-one feet deep. Seven miles from the Atlantic there is a range of mountains. Instead of digging the canal to sea level, the workers built locks for lifting boats part way up the mountains. These locks are huge tanks 1000 feet long and 110 feet wide. The ends are closed with steel doors seven feet thick. When a boat enters a lock, the doors are closed back of it and the tank is filled with water, which lifts the boat so that it can go forward at a higher level. A boat is lifted a total of 85 feet in three different locks. Near the Pacific end of the canal, another set of locks lowers the boat back to the level of the ocean.

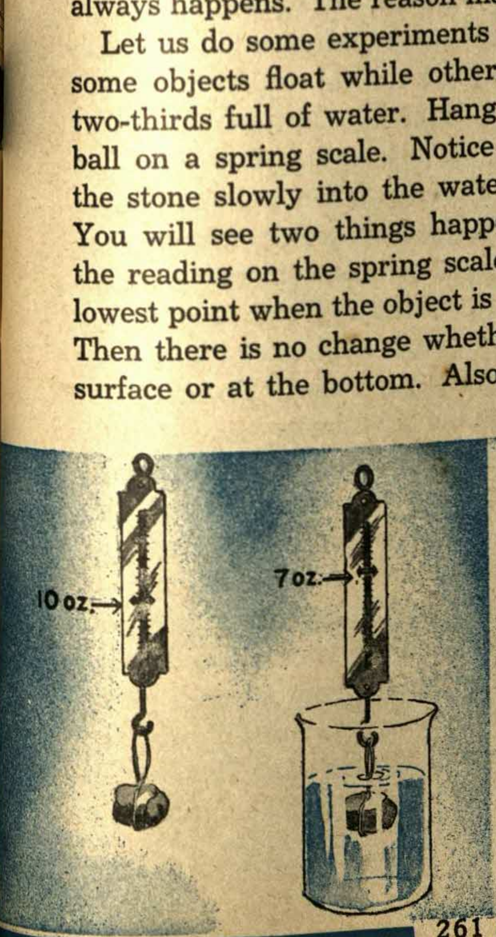
"Someone has calculated that enough earth and rocks were removed in building the canal to fill a train of cars 100,000 miles long."

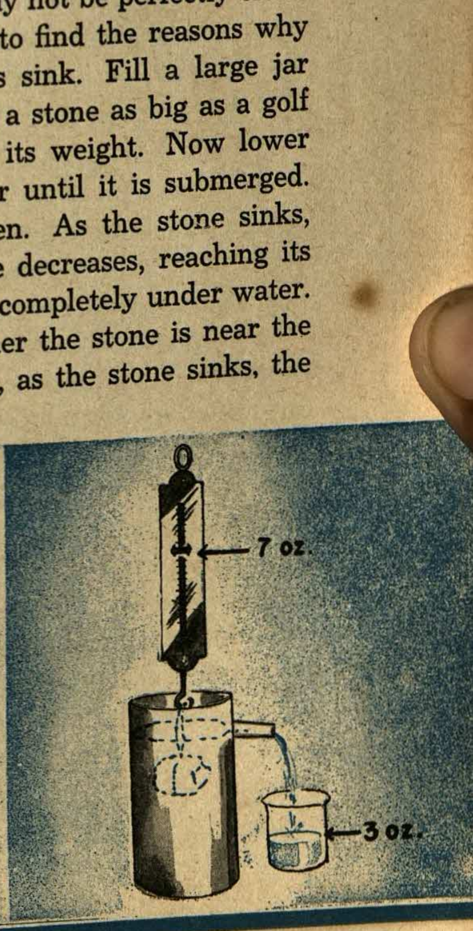
"Thank you, John. That was an interesting report."

Why do some objects float and others sink?

Toss a piece of wood and a stone into water. The stone sinks at once while the wood floats. We know that this always happens. The reason may not be perfectly clear.

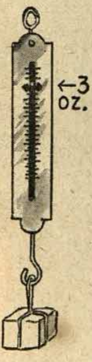
Let us do some experiments to find the reasons why some objects float while others sink. Fill a large jar two-thirds full of water. Hang a stone as big as a golf ball on a spring scale. Notice its weight. Now lower the stone slowly into the water until it is submerged. You will see two things happen. As the stone sinks, the reading on the spring scale decreases, reaching its lowest point when the object is completely under water. Then there is no change whether the stone is near the surface or at the bottom. Also, as the stone sinks, the



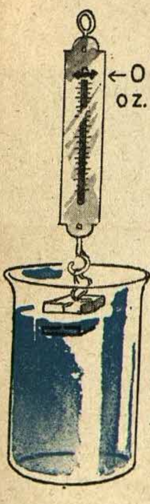


level of the water in the jar rises. The stone pushes water aside and takes up the space which the water originally occupied.

The stone seems to have lost weight. Of course, it does not really lose any weight, for gravity is acting on it while it is in water just as it does when the stone is in air, and the stone is as big as ever. Apparently, the water pushes upward on the stone, so that its entire weight is not pulling on the spring scale. The upward push of the water is a force which is called *buoyancy.*



Let us see whether there is any relation between the apparent loss of weight of the object and the amount of water which it pushes aside. Obtain a can like that shown in the diagram. (Page 261, right.) Pour in water until it overflows from the spout. When water ceases to flow, place a beaker, which has been weighed, under the spout. Lower the object into the can and note exactly how much weight seems to be lost. Weigh the beaker and the water which overflowed. Subtract the weight of the beaker to find the weight of water. You will discover that an object which sinks in water seems to lose in weight an amount exactly equal to the weight of the water that it pushes aside. This is an important fact that was first discovered long ago by Archimedes.

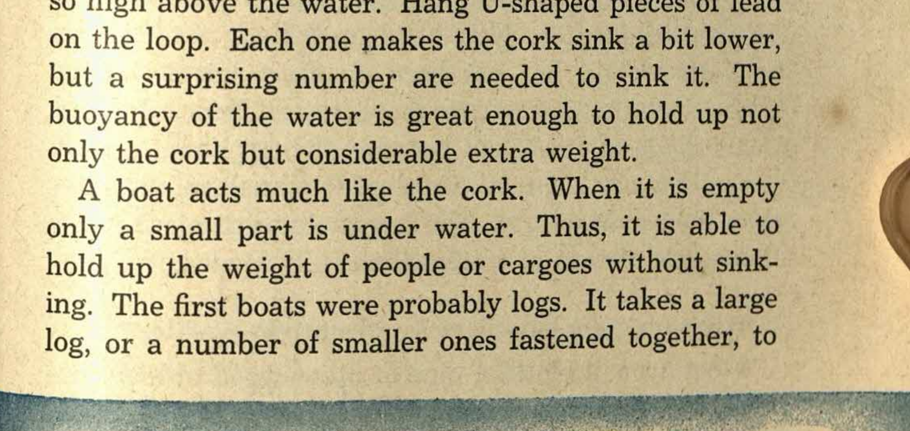


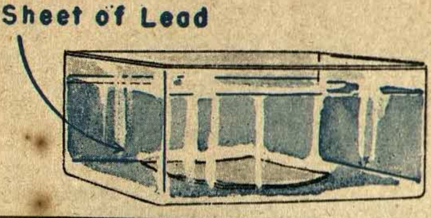
All of us know that two objects of the same size do not always have the same weight. Scientists say that such objects differ in density. Wood is much less dense than stone. Let us study what happens when a piece of wood is used instead of the stone. Hang the wooden block on the spring scale and lower it slowly into the water in the jar. As it goes down, the scale shows that

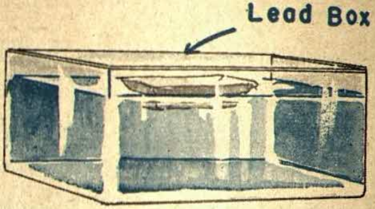
the block pulls less and less. Finally, the pointer goes back to the zero mark. At this point we notice that the block is floating. The water has enough buoyancy to hold up the entire weight of the wooden block. When we weigh the water which overflows, we discover that its weight is exactly the weight of the floating object. From this experiment, we conclude that any object will float if it can push aside, or displace, an amount of water equal to its own weight without being submerged.

If we drop a large flat cork stopper into water, it floats with little of it submerged. The density of the cork is so small that only a little water needs to be displaced in order to equal the weight of the cork. Now attach a loop of wire to the bottom of the cork. It still floats but not so high above the water. Hang U-shaped pieces of lead on the loop. Each one makes the cork sink a bit lower, but a surprising number are needed to sink it. The buoyancy of the water is great enough to hold up not only the cork but considerable extra weight.

A boat acts much like the cork. When it is empty only a small part is under water. Thus, it is able to hold up the weight of people or cargoes without sinking. The first boats were probably logs. It takes a large log, or a number of smaller ones fastened together, to







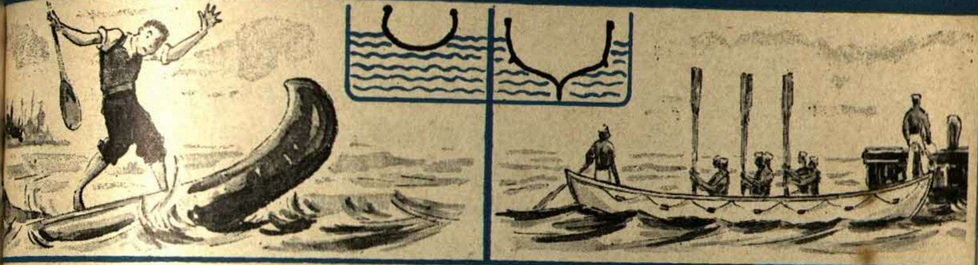
hold up the weight of even one person. If a log is hollowed out, the weight is reduced without changing its ability to displace water. This makes it possible for the log to carry a greater weight.

Most large ships today are made of steel. This may seem strange, for we know that a steel bar thrown into water sinks at once. But we know also that a tin can, which is really steel covered with a thin layer of tin, will float. Take a sheet of lead foil. It sinks when dropped into water. Now bend up the edges to form a box. Its weight has not been changed, but its shape is now such that it displaces more water. Hence it floats. Boats made of steel float because of their shape. They are hollow so that they can displace much more water than their own weight. The largest ships displace many thousands of tons of water when fully loaded.

What makes a ship float in an upright position?

Float a small block of pine or other wood of low density. Since it floats quite high it should be able to carry extra weight. Try placing weights on the top surface. You will discover that the weights must be placed in certain positions or the block tips over and the weights fall off. We say that the block is unstable.

It is very important that boats be made stable for



safety. We can get a clue as to how this is done by recalling the experiment in which we hung weights from the cork stopper. We had no difficulty in keeping the cork upright because the weights were attached to the bottom. The loads which are carried by boats cannot be hung from the bottom, but they are placed as low in the boat as possible. On large boats the engines and other heavy machines are placed at the bottom of the boat. Heavy cargo is placed in the lowest parts and is stacked so there is equal weight on both sides of the center of the ship.

Canoes and some other small pleasure boats are quite light in weight. Consequently, they float high in the water. If one stands in such a boat, or leans over the side, it may tip and throw one overboard. When properly used, such boats are safe.

Why did water transportation develop before land transportation?

In the early days in this country almost all travel and shipment of freight were by boats that travelled along the seacoast and on the rivers. Water furnishes a ready-made roadway which costs nothing to build and little or nothing to maintain. The only structures that must be provided are docks where boats can land.

The friction of a boat passing through water is very much less than the friction of the same boat on land. If you have ever dragged a rowboat out of water, you are familiar with this difference. While the boat is in water, a light push will move it a long distance. On land, it takes a vigorous push to move it a few inches.

The force needed to move a ship through water is small enough so that the wind can be used to propel it. Long before the invention of engines suitable for driving vehicles on land, sailing ships of large size had been built. They made possible the use of energy that did not come from the muscles of men and animals.

How does a navigator tell his position?

Every globe and every map are crossed by lines. Some of the lines are drawn parallel to the equator. The others connect the North and South Poles. The lines parallel to the equator are lines of latitude; the others are lines of longitude. Each line is numbered in degrees, which is the usual unit for measuring circles.

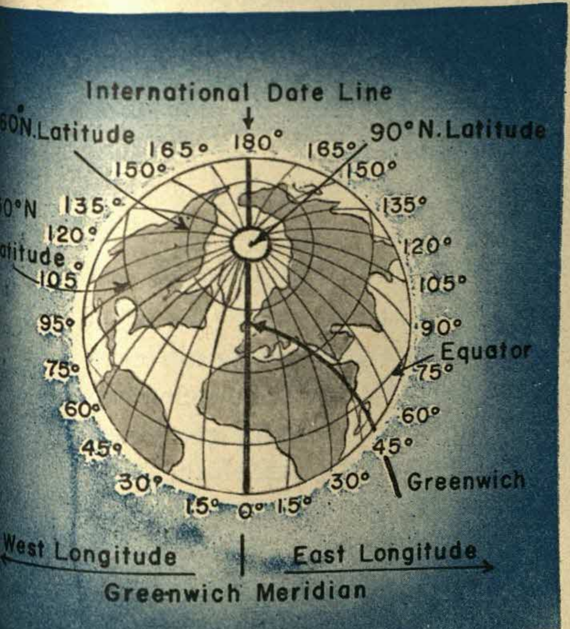
The equator is the starting point for measuring latitude and is marked zero. The North Pole is 90 degrees north latitude and the South Pole is 90 degrees south latitude. The zero longitude line runs through Greenwich, England, and is called the prime meridian. Longitudes are measured in degrees both east and west of this line. In order to make the measurements more exact, a degree is divided into 60 minutes and a minute into 60 seconds.

The location of any place on the earth can be expressed exactly by giving its latitude and its longitude.

For instance, suppose a place is located at 28 degrees north latitude and 100 degrees west longitude. If you examine a globe you will find that this point is on the Rio Grande River. No other place in the world has the same latitude and longitude.

When a ship is on the ocean, its position is known accurately when its latitude and longitude are known. But how can these be found for a ship which is moving constantly? There are no signposts to guide one on the ocean—except the sun and stars. It is by observation of these that a navigator determines the position of his ship.

An instrument, known as a sextant, is used to determine the latitude. The sextant is held in such a position that the horizon can be seen through its small telescope. Then the arm is moved until the sun appears



Using the Sextant

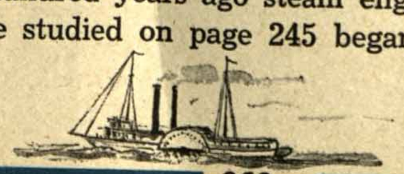
to rest on the horizon as seen in the mirror in front of the telescope. The degrees, read from the curved scale at the bottom, give the angle between the sun and the horizon. The navigator is then able to tell his latitude from this angle by referring to tables.

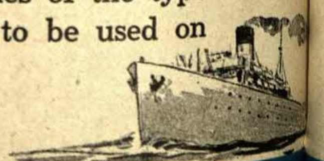
The longitude is determined by the use of two accurate clocks, called chronometers. One of them is always set to Greenwich time. The other clock is set to local time by observing the position of the sun. Suppose it is noon by the chronometer set to local time when it is 3 p.m. by the chronometer set to Greenwich time. The navigator knows that he is west of Greenwich since his clock is earlier. He also knows that for every 15 degrees west of Greenwich the time is an hour less. Thus he knows that three hours' difference in time means that he is at 45 degrees west longitude.

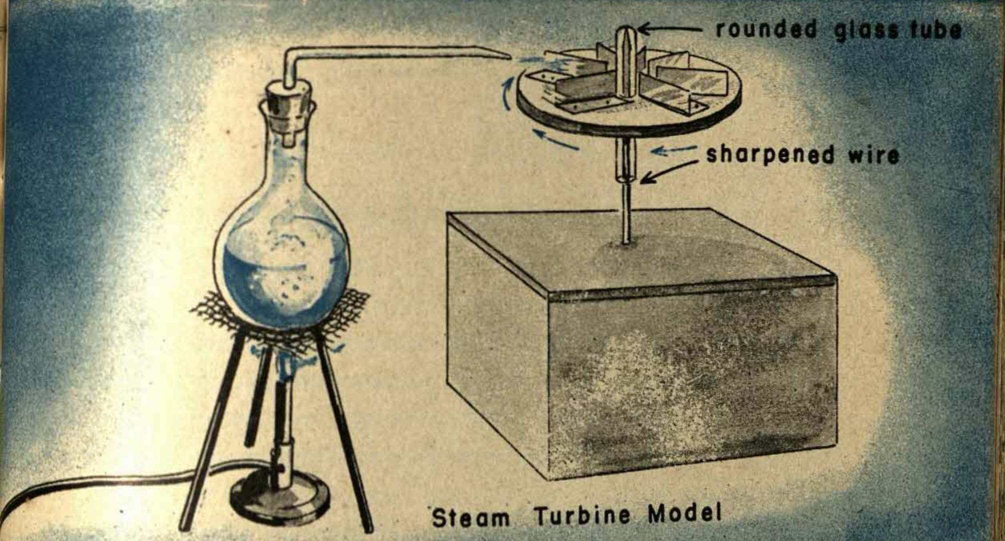
Since radio communication has been developed, better ways have been worked out for determining the location of a ship. Clear weather is necessary in order to determine location by observations of the sun and stars. Radio beams are not affected as much by the weather as are light beams. Hence the radio method is more dependable.

How have the steamboat and turbine changed our lives?

Boats have been propelled by a great many different forces. Paddles and oars wielded by human muscles and sails driven by the wind have been used for centuries. Over a hundred years ago steam engines of the type which we studied on page 245 began to be used on







Steam Turbine Model

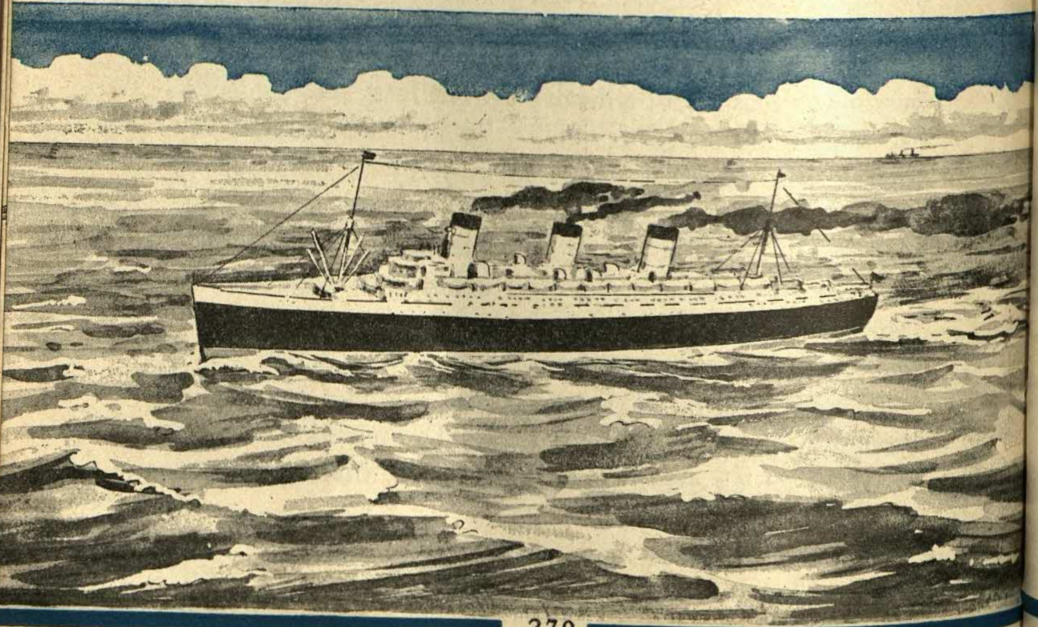
ships. Ships driven by engines can follow a regular schedule and are faster than most sailing ships.

In recent years, two important types of engines have been developed which have improved the speed of ships. Large Diesel engines, somewhat similar to gas engines, but without spark plugs, are used in many freight and passenger vessels of medium size. The largest and speediest ocean liners are driven by steam turbines. In the turbine, the steam is not used in cylinders, but jets of steam are blown against the blades of a wheel somewhat like a pinwheel, or a windmill enclosed in a case. The force of the steam spins the turbines so rapidly that they can drive boats at high speeds. The great ocean liners can cross the Atlantic in about four days.

The drawing on this page shows a model of a steam turbine which can be easily built. The wheel is a round board to which are fastened several tin blades, set vertically. Through the center is inserted a glass tube closed at its upper end.

A sharpened wire sticks up from a board and on this the wheel is pivoted. The glass tubing serves nicely as the bearing. When the steam from boiling water in a flask is directed against the blades, the wheel spins rapidly. The turbine which drives an ocean liner contains a spinning wheel which is operated in a similar way.

There are regular steamship lines connecting all the principal seaports. They carry freight in huge amounts as well as thousands of passengers. They make it possible for us to have goods and luxuries from all parts of the world. The speed with which people and goods are carried by modern ships has the effect of making the world seem smaller. People all over the world have come to know each other better because of the low cost and the speed of modern ocean travel.

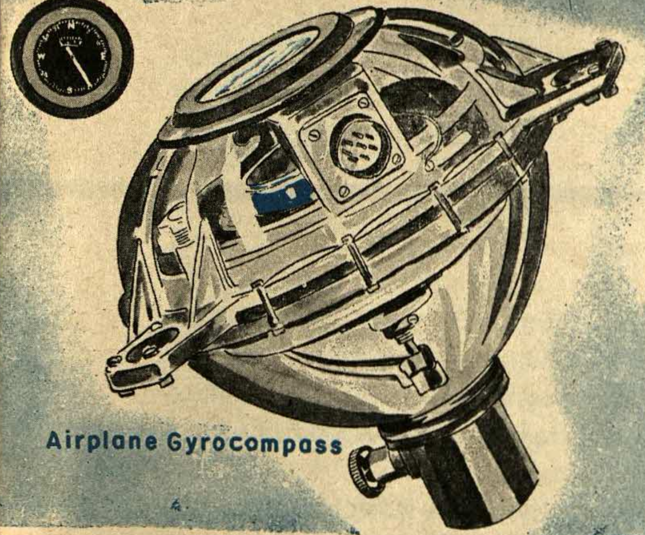


Through the Air

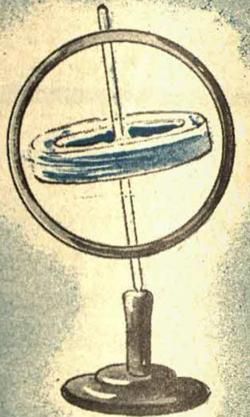
A top is an interesting toy because it does not seem to be affected by gravity. As long as a top is spinning, it remains in an upright position even though it is supported only by a point. It topples over as soon as motion stops.

In 1832 Professor W. R. Johnson invented a peculiar kind of top, called a gyroscope. It consists of a heavy wheel mounted in a frame of rings which are free to turn. For a long time, this top was little more than a toy. Thousands of boys and girls have been amused by it; for when the wheel is set spinning rapidly, the top can be perched in the most unstable positions without falling. The heavy spinning wheel resists strongly any force which tends to change its position.

About forty years ago an American inventor, Elmer A. Sperry, became interested in gyroscopes. He saw that the tendency of the rotating wheel to stay in a fixed position could be used to do many useful things. For instance, if an electrically driven gyroscope is set going with its axis pointed toward the sun, it keeps pointing toward the sun even though the earth turns constantly. Sperry used this fact in building his gyrocompass. When the gyrocompass is set to point in a certain direction, it continues to point in that direction no matter how



Airplane Gyrocompass



Gyroscopic Top

much the object to which it is attached moves. The gyrocompass is not affected by iron objects as is the common magnetic compass.

The gyroscope has provided the means for solving many of the problems of flight in airplanes. As long as a pilot can clearly see the earth below him, he can steer his plane and keep it on an even keel. At night or in cloudy weather, he has nothing by which to judge whether he is flying a straight course. He may travel in circles, or toward the earth or tilted at an angle without being aware of it. A number of different instruments have been invented which make use of the ability of gyroscopes to stay in a definite position. Thus, they can show the pilot at any moment or in any kind of weather when he is changing from the right course.

A marvelous use of the gyroscope is in the automatic pilot for airplanes. When once set for a certain direction, the automatic pilot keeps the plane flying on that course without any attention whatever from the human pilot.

Why does a balloon rise in air?

On page 263 we learned that any object will float on water if it can displace an amount of water equal to its own weight. If the object can displace more than its own weight of water, it can float even when additional weights are added.

Like water, air exerts buoyancy on objects immersed in it. Objects in air displace the air, which pushes them up in the same way that water does. Of course, air weighs much less than water, so that the upward push of displaced air is much less than the upward push of displaced water. As a matter of fact, however, all objects weigh a little more in a vacuum than they do in air. In the air an object is pushed upward by a force equal to the weight of the air displaced, just as an object in water is pushed upward by a force equal to the weight of water displaced. Since a cubic foot of air weighs only about an ounce and a quarter, an object which occupies a cubic foot of space will be pushed up by only this small amount. Ordinarily we are not aware that the air pushes at all because its push is so small in comparison with the weight of common articles.

Nevertheless, it is the small upward push of the air that holds up balloons. A balloon must be made light enough to displace a greater weight of air than its own weight. This is accomplished by making a large bag and filling it with some gas which is much lighter than air. The Montgolfier brothers made the first successful balloons, using very large paper bags which they filled with hot air. As the air cooled, its volume shrank. The balloon then lost its buoyancy and returned to the earth.

Hydrogen is the lightest gas known. It is only about one-fifteenth as heavy as air. This makes hydrogen the best gas for filling balloons if we wish the balloon to lift the greatest possible weight. The toy balloons which are sold at fairs and carnivals are sometimes filled with hydrogen. The hydrogen used for this purpose is compressed into strong steel tanks and released through a valve into the balloon.

Hydrogen has one serious disadvantage when used in balloons. It burns very readily and, when mixed with air, it will explode when ignited. A number of lives have been lost as a result of fires in balloons which have been filled with hydrogen. Some years ago large airships, known as *dirigibles,* were built to carry passengers and freight across the ocean. They were kept afloat by large chambers filled with hydrogen. The hydrogen in one of these dirigibles, the *Hindenburg,* exploded, and the ship fell to the ground in flames.

In this country, balloons are often filled with helium. This gas will not burn. It is not quite so light in weight as hydrogen, and so a balloon filled with helium will not lift as large a weight as the same balloon filled with hydrogen. However, the small loss of lifting force is more than offset by the greater safety. Helium was first observed in the sun. The gas was later found in the earth's atmosphere in very small amount. The only large source of helium thus far discovered exists in certain natural gas wells of western United States.

How have balloons increased our knowledge of the atmosphere?

Balloons have not been very successful for transportation through the air. Balloons which are not driven by engines must depend upon the wind to carry them along. They cannot be steered easily. They will rise until the air is so thin that it no longer exerts an upward force on them. They can be brought down only by letting some of the gas escape.

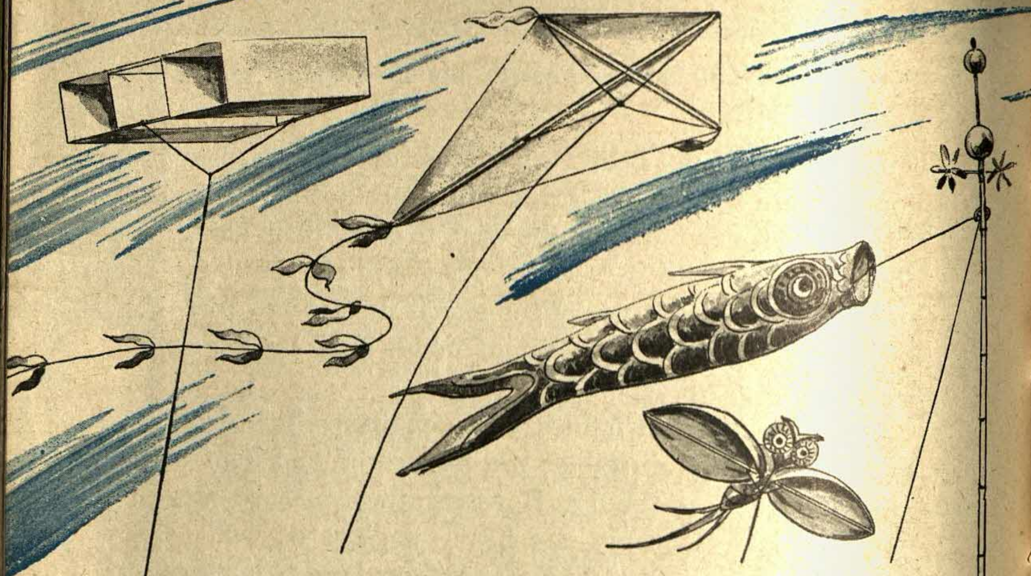
Balloons, called dirigibles, carry engines which drive propellers. These dirigibles can be steered and kept at a certain height in the air. However, they must be very large in order to carry the heavy engines as well as passengers and freight. This makes them hard to manage when they land. If filled with hydrogen there is danger of fire. Hangars for storing them are large and expensive.

Balloons are useful to scientists. Much of our knowledge of the upper atmosphere has been gained from the flights of balloons into the stratosphere. It is possible for balloons to go much higher than airplanes. Weather stations use small balloons to study the conditions of the upper atmosphere in order to make predictions.

In wartime, barrage balloons are anchored by long cables around important cities to interfere with attacks by bombing planes.

What makes a kite fly?

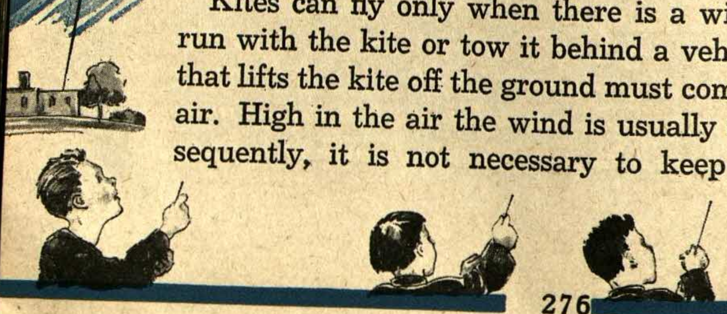
Men have always envied birds for their ability to leave the solid earth and soar through the air. History gives us many stories of people who tried to fit wings

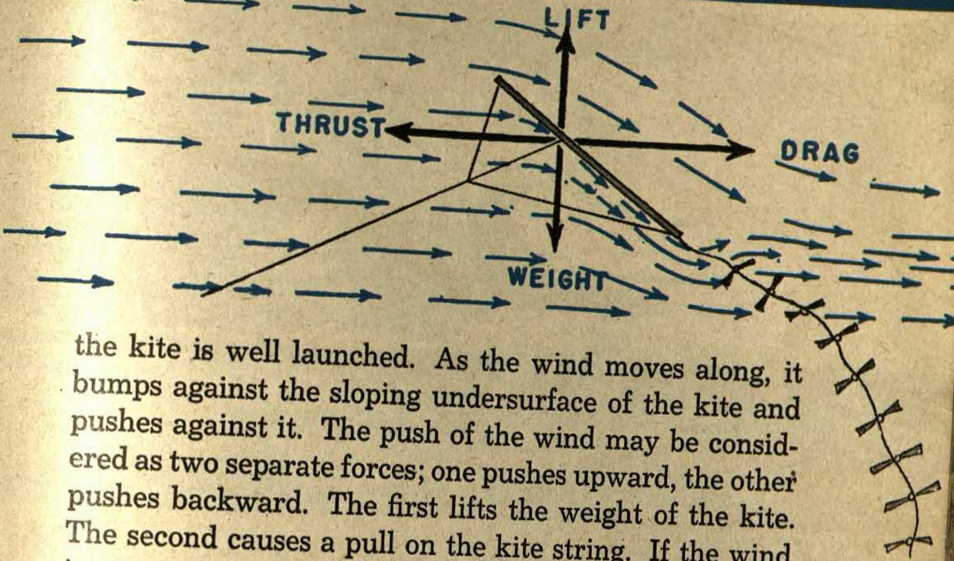


to their bodies. They always met with failure because a man does not have sufficient strength to operate wings large enough to support his heavy weight in the air.

For many centuries people have used kites. These can soar into the air and do not need a bag of gas to keep them afloat. It was by a study of kites and a similar device, the glider, that we learned how to make and to fly airplanes. A simple kite consists of a light wooden frame covered with thin paper. A string is attached in such a way that the kite is always held at an angle in the air with one end higher than the other. Usually a tail is attached to the lower end.

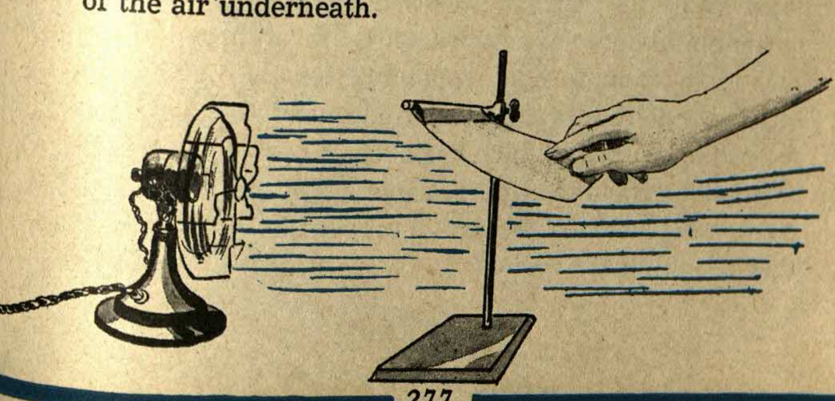
Kites can fly only when there is a wind, unless you run with the kite or tow it behind a vehicle. The force that lifts the kite off the ground must come from moving air. High in the air the wind is usually stronger. Consequently, it is not necessary to keep running once

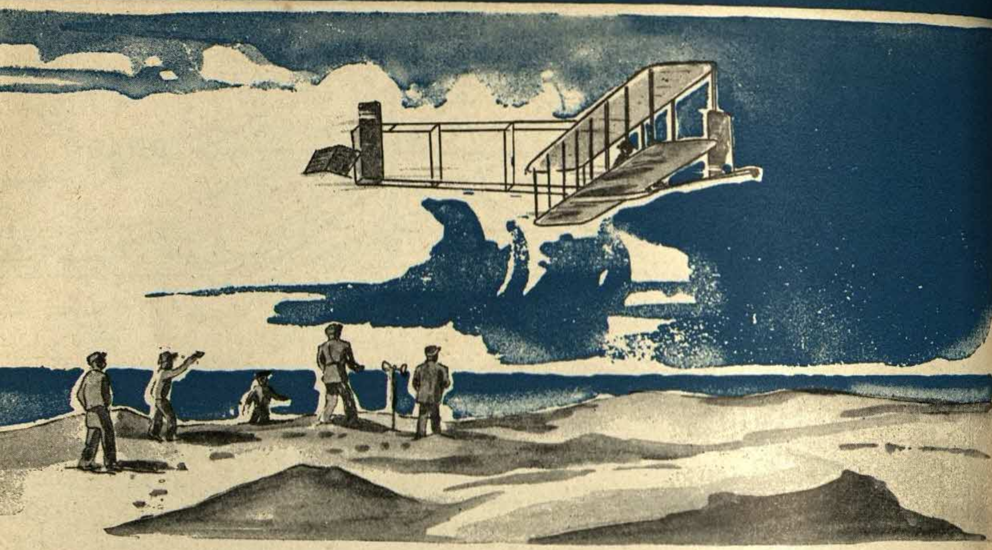




the kite is well launched. As the wind moves along, it bumps against the sloping undersurface of the kite and pushes against it. The push of the wind may be considered as two separate forces; one pushes upward, the other pushes backward. The first lifts the weight of the kite. The second causes a pull on the kite string. If the wind is great, the push may be enough to lift more than the kite. Kites have been built to carry instruments for measuring weather conditions. Other kites have been made which will lift a person.

A very simple experiment shows how moving air exerts a lifting force. Make a loop in one end of a piece of fairly stiff paper and insert a pencil. Hold the paper in front of an electric fan. The air strikes the paper and holds it up at an angle. By pushing downward on the upper surface of the paper, you can feel the upward push of the air underneath.

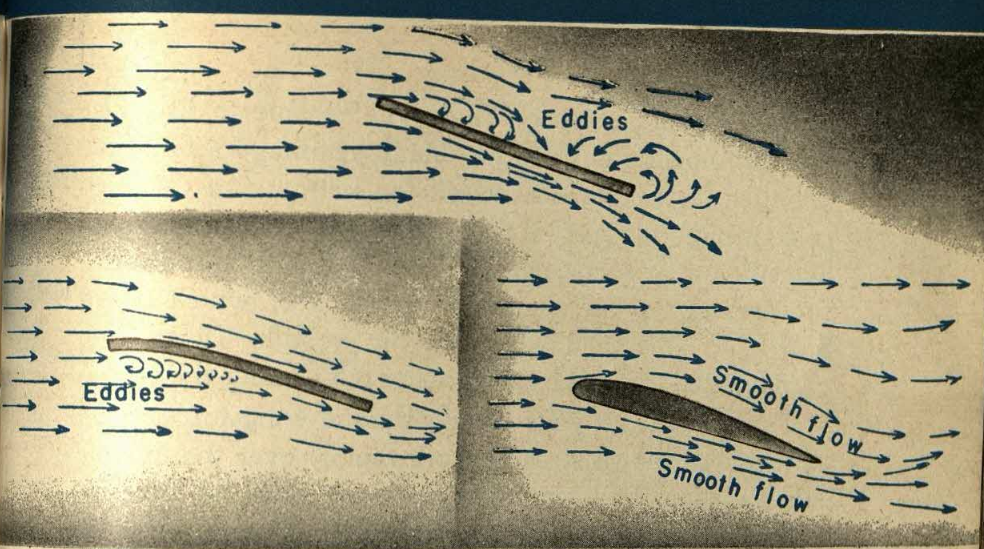




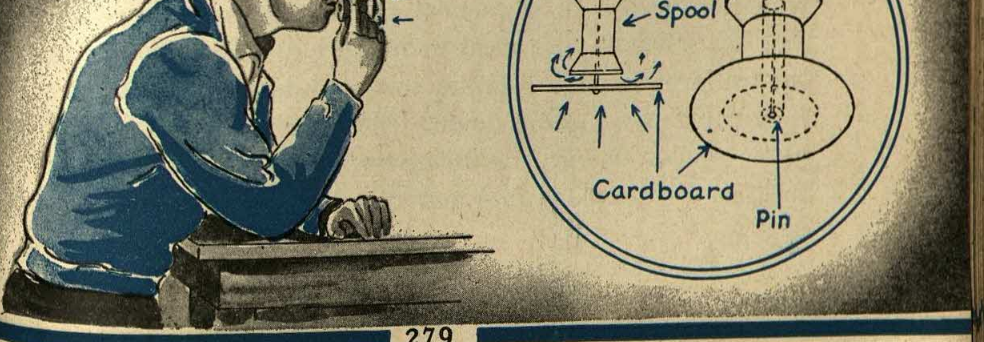
How is an airplane like a kite?

Many of the early airplanes were really gliders, for they had no engines to drive them. They were made in many different shapes and sizes, but all had kite-like wings to support them. They also had a tail to steer with, just as a kite has a tail to keep it in the proper position in the wind. From the study of gliders some very important things were learned about the proper shape for airplane wings. It was found that air which streamed over the upper part of a flat wing swirled about in eddies, as shown in the diagram. This reduced the lifting effect.

Some gliders were constructed with a curved wing. This allowed air to flow smoothly over the upper surface, but eddies now appeared underneath. The answer seemed to be a wing which had a flat or nearly flat undersurface and a curved uppersurface. Wings of this shape were constructed and were found so satisfactory that they are still used today.



Not only did the thick wings prevent the swirling of air about them but they created a new force which helped to lift the wings. Let us do an experiment to show this. Place a common pin through a cardboard disk two or three inches in diameter. Place a spool over the card so that the pin projects into the hole. Blow vigor-

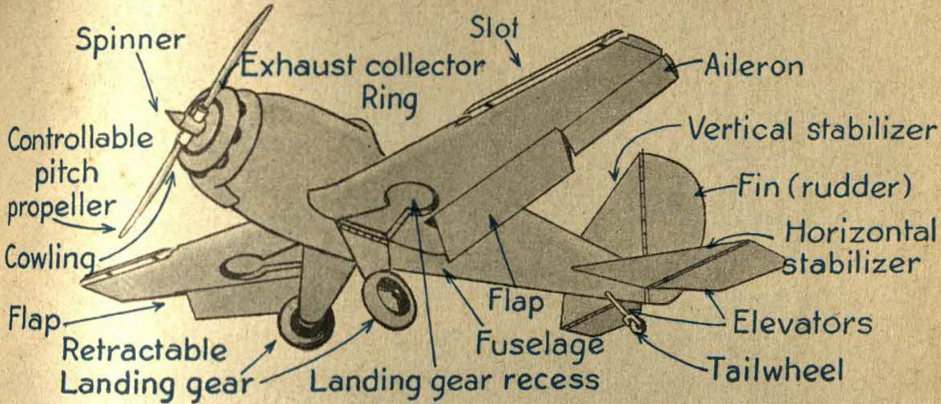


ously through the spool. You will be able to lift the card by blowing downward. Many years ago a famous scientist, Bernoulli, discovered the reason. As the air goes through the spool it rushes outward in all directions over the upper surface of the card. Bernoulli found that the pressure of air against a surface over which it is flowing is less than when the air is still. Thus, the card is lifted upward by the greater push under the card.

The thick front edge of an airplane wing forces the air aside so that it streams more rapidly over the upper surface than the lower. This gives an extra lift that is useful in supporting the weight of the plane.

Both kites and gliders depend upon wind to support them. Winds are variable. They cannot be depended upon to provide an even force. In an airplane, propellers driven by engines screw their way into the air, thus moving the wings steadily through the air. Thus propellers create the wind which lifts the plane. The propeller also drags the plane forward. The gasoline engine is used to turn the propellers because it can be made very powerful and yet not too heavy.

The flight of airplanes is controlled by several movable surfaces. Hinged to the back edge of the wings are *ailerons,* which can be raised and lowered to cause the plane to tilt when it makes a turn. On the tail is a *rudder,* which is hinged in a vertical position to swing right and left. This is also used in making a turn. Also on the tail are *elevators,* similar to the rudder except that they can move up and down. They are used when the plane moves upward or downward. The steering surfaces move the plane in a new direction because the air



presses against them when they are held at an angle to the motion of the plane.

How has air travel changed our lives?

On both land and water, the speed of motion can be very slow, or it can be increased to a point where friction makes further speed impossible. On water, speeds of thirty or forty miles an hour are considered high. On land, speeds of more than a hundred miles an hour cannot be maintained for long distances. But with planes the slowest speeds are as great as the highest speeds on water. Many planes, regularly used to carry freight and passengers, travel more than two hundred miles per hour, and they maintain these speeds for hours at a time. The high speed of an airplane is due to the small amount of friction encountered while moving through air.

The great speed of air travel makes it possible to reach almost any place on the earth from any other place within a few hours or a few days. It is not at all unusual for a person to eat breakfast in one city and to eat dinner at another, hundreds of miles away. Planes are now large enough to carry rapidly many tons of goods of all kinds. Foods can be carried so quickly that they arrive nearly as fresh as when gathered.

Airplanes make it possible to reach remote places where travel by land is very slow Mines have been opened in mountainous regions and in the wilderness where there are no roads, railroads or navigable rivers. Machinery and supplies are flown to the mines, and the mineral products flown out.

In times of disaster, medical supplies, food and clothing can be sent quickly. Forest fires are spotted from planes, and fire-fighters with their equipment are dropped by parachute to fight the flames. Airplanes are used to spread poisons over fields and forests in order to control insects. Large areas that would require days or weeks to be sprayed by other means can be sprayed by airplanes in a few minutes.

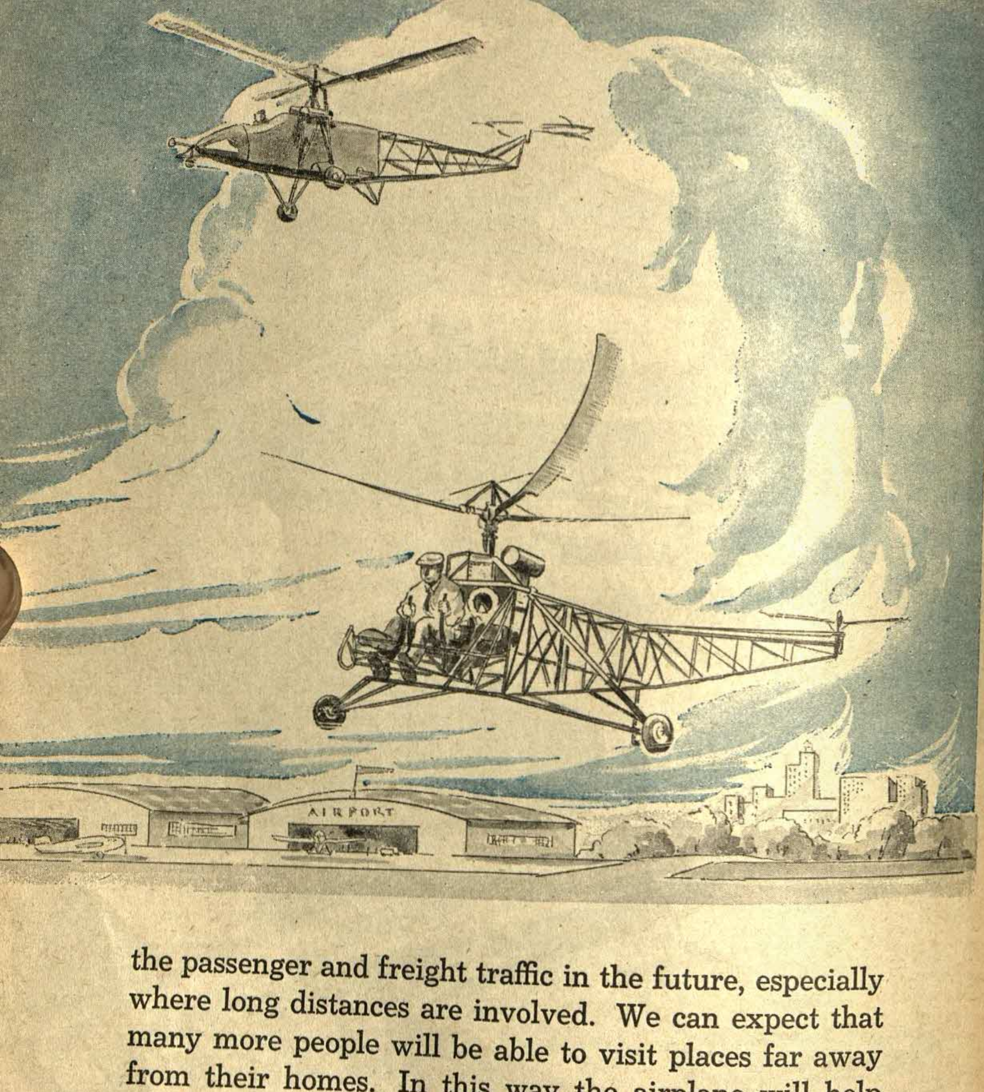
What are some likely future changes in air travel?

Modern planes require large fields for taking off and for landing. Many experiments have been carried on with aircraft that can take off and land vertically. The helicopter is a craft of this type Such improved aircraft may soon be in common use.

Much training and skill are required to operate planes safely. As was the case with automobiles, the planes of the future will be so designed that many people will be able to operate them easily and successfully.

There is little doubt that planes will carry much of

U.S. MAIL
AIR EXPRESS



the passenger and freight traffic in the future, especially where long distances are involved. We can expect that many more people will be able to visit places far away from their homes. In this way the airplane will help people of different countries to know and to understand each other. They will learn to depend upon and to get along with each other.

Things to Do

1. Make a collection of pictures of animals which man has used to do his work.
2. Make a report to the class on the materials which various peoples have used in constructing boats.
3. Prepare a notebook with illustrations of the various methods of land transportation.
4. Prepare a notebook with illustrations of the development of transportation on water.
5. The submarine is an interesting type of boat. Appoint a committee to study the submarine and to report on how it works.
6. Secure a large bottle with flat sides. Fill it nearly full of water and place in it a medicine vial which contains enough air to make it float. Put a cork in the large bottle and twist it in until the vial barely floats. By pressing the flat sides of the bottle firmly, you can make the vial sink. This is called a Cartesian diver. Explain how it works.
7. Secure a disk of thin metal about three or four inches in diameter. Punch a hole in the center about one-eighth of an inch in diameter. With a pair of tinsnips, cut halfway from the edge to the center every half inch around the outside. Twist each piece of metal until it is nearly crosswise to the disk. Mount the disk on a stiff piece of wire through the hole in the center and hold it firmly in place with thin pieces of wood pressed over the wire on either side. This is a crude turbine. When it is mounted so that it turns freely, it can be made to spin rapidly by a jet of steam blown at it from a tube fitted to a flask in which water is being boiled rapidly.
8. Make a large chart for the science room showing how a gasoline engine works.

9. Make a large chart for the science room showing how a steam engine works.
10. Not all the fine highways have been built recently. The ancient Romans built some splendid roads. Prepare a report on "Roads—Past and Present."
11. Make or collect model airplanes of different designs. Find the reasons for the different designs.

How Much Do I Remember?

The following question is written in code. Directions for solving the code are given below. *Please do not write in the book.*

Question: M O W E X P U X W X O I B P A D Y E I F?

Directions for solving the code:

M — If derricks were used in building the Pyramids of Egypt, change to S. If gravity is a resistance that often must be overcome in moving things, change to W. Otherwise, change to A.

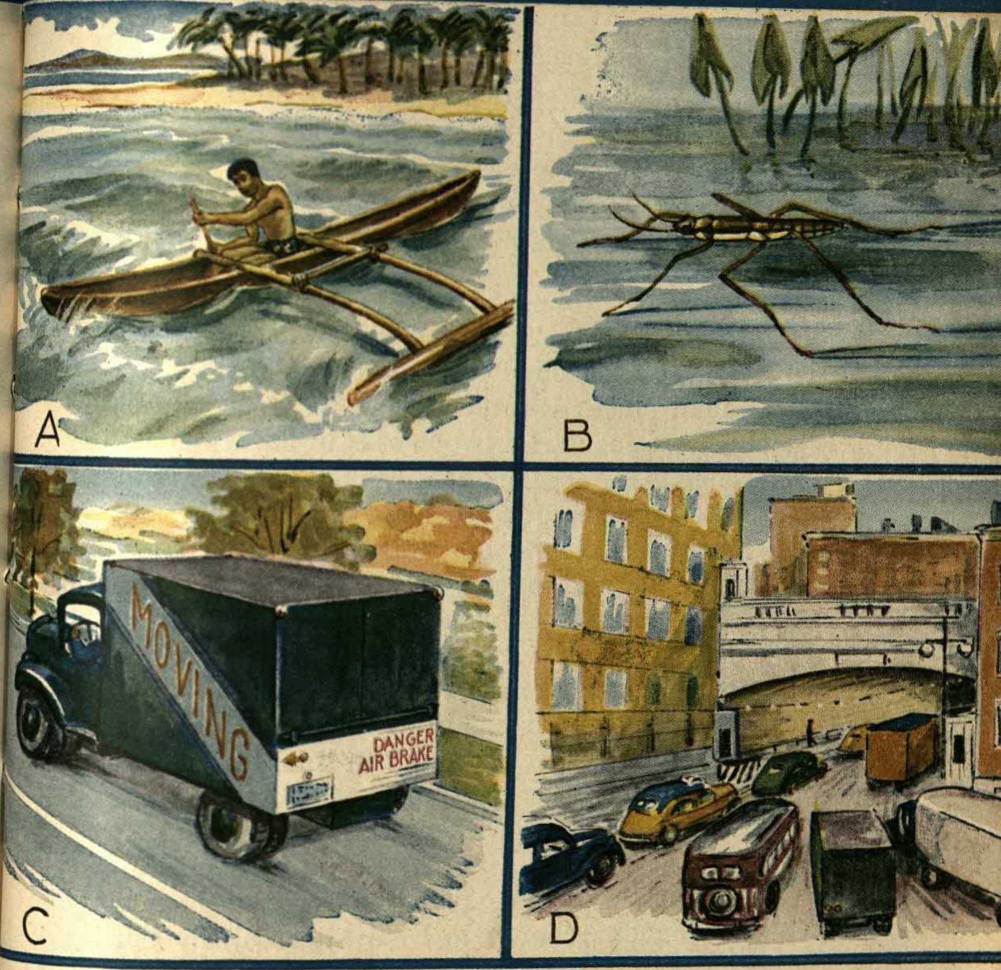
O — If friction is greatest between smooth surfaces, change to B. If inertia is the ability to do work, change to C. If muscles are made of bundles of cells, change to H.

W — If camels are used as beasts of burden, change to A. If man has a better digestive system than other animals, change to T. If moving air possesses no energy, change to Y.

E — If windmills are run by atmospheric pressure, change to O. If moving air exerts more force than running water, change to R. If moving air removes dust from carpets into a vacuum cleaner, change to T.

X — Is the space between words and should be left blank.

P — If a projectile is pushed from a cannon by hot gases, change to I. If a rocket is moved by an explosion under it, change to M.



A. Why is the log fastened to the side of the boat? Why did not the American Indian use such canoes? How are certain modern canoes built so as to make them more stable?

B. How can this insect stay *on top* of the water? Find out whether the body of a housefly is lighter or heavier than water.

C. How can air be made to operate brakes? Who invented the air brake?

D. How can highway tunnels be kept free of the poisonous fumes from automobiles? Prepare a report to be read to the class, on how highway tunnels are built under rivers.

U – If steam is produced in the cylinder of a steam engine, change to C. If the Alaska Highway runs from Mexico to Panama, change to J. If the wheel is one of the most important inventions, change to S.

I – If ball bearings are used in bicycles, change to E. If small wheels roll more easily than large wheels over rough ground, change to F. If friction is always undesirable, change to G.

B – If highway accidents occur most frequently on straight wide roads, change to W. If highways only wide enough for two lines of traffic are safest, change to M. If many highway accidents are due to the carelessness of drivers, change to L.

A – If railroads were first built in 1750, change to B. If railroads and automobiles have made it possible for goods to be shipped almost everywhere, change to C. If automobiles were first invented in 1800, change to D.

D – If the Panama Canal is entirely at sea level, change to A. If any object floats when it is lighter than an equal volume of water, change to O. If modern balloons are filled with hot air, change to U.

Y – If the gyroscope is an important aid in navigating airplanes, change to P. If hydrogen is heavier than helium, change to I. If kites will fly best when the air is perfectly quiet, change to G.

F – If ailerons are used in making a plane climb, change to Z. If airplanes are lifted entirely by the backward push of air against the underside of the wings, change to D. If airplanes are sometimes used to spread poisons on crops, change to R.

ENERGY FOR COMMUNICATION

Speaking and Hearing

Major Hingston was a scientist who devoted his life to the study of insects. On the plains of India he found a kind of ant which interested him very much. He decided to perform an experiment. Locating an ant which was searching for food, Hingston threw her a caterpillar. The ant examined the caterpillar, tried to drag it back toward the nest and failed. It was too big and heavy. She started back to get help, but Hingston caught her, marked her with a spot of yellow paint and then let her go.

In a few seconds, hundreds of ants rushed out of the nest and made for the caterpillar. The marked ant was in the center of the swarm, though she was not the leader. As soon as Hingston saw her, he picked her out of the group and threw her aside. Yet, the rest of the ants knew how to find their way to the caterpillar. They followed the exact path used originally by the marked ant. It seemed as if this first ant had left her scent which still lingered along the path. Even though hundreds of ants had crossed the path of the ant that had found the caterpillar, none of them seemed to have any trouble in picking out that one particular path.

The amazing thing about the experiment is this. How did the first ant relay the news of her discovery to the army of ants? How did they know that food had been found?

How do animals communicate with each other?

Animals cannot speak, but parrots, macaws and cockatoos can be taught to imitate the human voice. But do animals understand each other? Many scientists believe that they do. Marmots and chamois seem to have leaders and watchers. The leaders guide the others by means of calls. The watchers warn their fellows of approaching danger.

You may have heard one cat answer the call of another, or one dog answered by another dog. Apes have voices, too. They generally communicate with each other by shrieking or screaming. The baby orangoutang cries like a human baby when it is hungry. When gorillas are excited, their screams may be heard in the jungle.

Next to man, birds excel other animals in their ability to communicate with each other. The cackling of geese, the drumming of woodpeckers and the chattering of magpies are familiar sounds to those who live in the country. The common pullet can make thirteen different sounds and the cock can make fifteen. The turkey is even more accomplished.

Some insects make sounds with different parts of their bodies. The cricket makes noises by rubbing the edge of one wing against the other wing. Grasshoppers

play their "violins" by scraping the rough edges of their wings against the upper part of their legs.

There are many animals which can communicate with each other without making sounds. Ants communicate with each other silently. The goose can signal to other geese by moving its neck into different positions. Are the gestures made by animals a kind of communication? Is the bristling of a dog's coat or a cat's tail or the ruffling of a hen's plumage a signal to its fellows? We are not certain of the answers. There is much more to be learned about the subject, even though scientists have studied animals for a long time.

How are sounds produced?

John Tyndall was a great man of science who performed many experiments with sound. He was once addressing an audience in a large lecture hall.

"Ladies and gentlemen," he said, "in the basement two floors below is a small music box. It is playing

now, but we do not hear it. The sound it makes is sending ripples into the air. Between us and the music box there are floors and doors which keep the air ripples from reaching our ears. But here is a rod which comes up from a hole in the floor. The rod is a long one, for its lower end rests on the music box in the basement. Will some one please come forward and put his ear to the rod?"

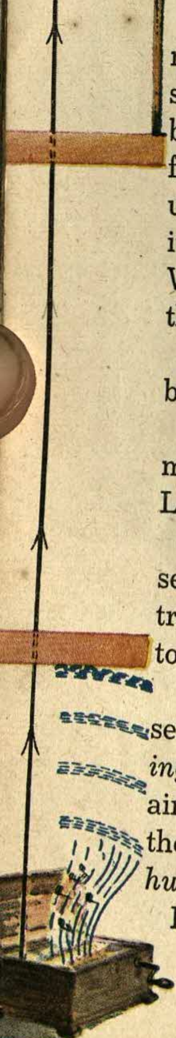
Some one did, and reported that he heard the music box playing.

"Now, so that everyone in this room can hear the music, I attach this wooden tray to the top of the rod. Listen carefully! Do you hear?

"You see, the quivering rod is narrow and does not set much air in motion, but when the rod causes the tray to move, the latter starts air ripples large enough to affect the ears of every person in the room."

Tyndall used this experiment to emphasize three essential ideas about sound. First, there must be a *sounding body*. Second, there must be some substance, like air or a rod, through which the sound may *travel*. Third, there must be some device to receive the sound—*the human ear*.

Let us perform experiments to illustrate these ideas.



Ask your teacher to lend you a tuning fork. Strike the prongs sharply and then bring them to your ear. Do you hear the sound? Now grip the prongs in the palm of your hand. Do you feel the vibration?

Sound the tuning fork again and plunge the ends of the prongs into a jar of water. Note how the vibrating prongs spatter the water in all directions.

Stretch a rubber band with one end held between your teeth, and pluck it. You can see it vibrate back and forth. You also hear a sound.

If you have a drum, place a cork near its middle and strike the drum. Note how the cork jumps into the air. The vibrating drumhead made it jump.

Each of these experiments shows that sounding bodies vibrate. Whenever you hear a sound, an object is vibrating somewhere.

How are sounds produced in the human voice box?

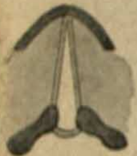
Our organs of speech depend upon the lungs. The energy of the sound is obtained from a stream of air produced in the same way as in breathing.

Place your fingers on your throat as you talk or hum. Do you feel the quivering in the windpipe? The vocal cords are vibrating.

VOCAL CORDS

Blow between two narrow strips of paper. Do you hear the sound. Do you see the vibrations of the paper. In both instances, sound is produced by the rush of air against something which is free to vibrate.

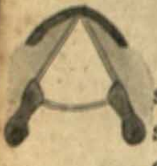
In the throat there is a voice box, or larynx. It contains two membranes, separated by a narrow slit. They are the *vocal cords,* which enable us to speak and to sing. Normally the membranes lie flat alongside the windpipe. In speaking, the cords are pulled into the windpipe and air from the lungs causes them to vibrate. It is important to note that sounds are produced where contact with the air can be made. The air is needed to carry away the sounds made in the voice box.



SPEAKING

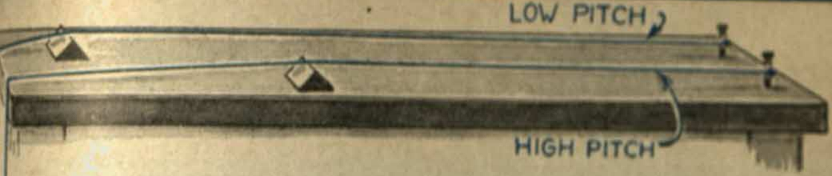
How may sounds differ?

Musical tones, even when produced by the same instrument, differ from one another. Some are high and some are low. The highness or lowness of a tone is called its *pitch.*



BREATHING

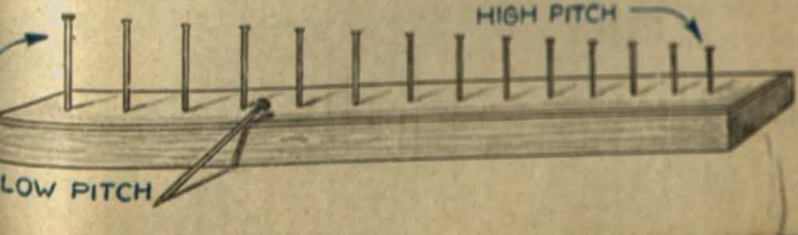
When does a string produce a note of low pitch and when one of high pitch? If we watch a sounding string carefully we see little difference in the way it vibrates for a high tone or for a low tone, but that is because our eyes cannot follow an object that moves so rapidly.

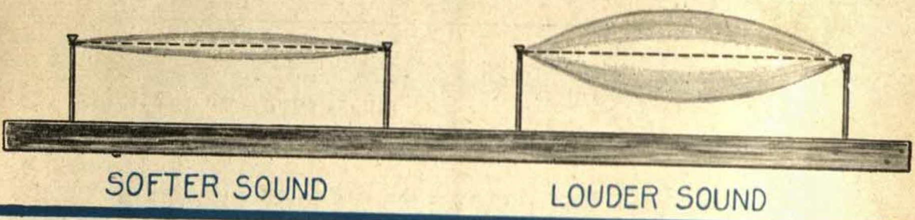


A slow-motion moving picture of a vibrating string would show that a high-pitched string vibrates more rapidly than a low-pitched one. In fact, the pitch of a sound depends on the speed of vibration of the sounding body.

Did you ever hear an automobile or a subway train start to move? The pitch of the sound goes higher and higher as the speed of the motor increases. The fire-engine siren is also an example of pitch increasing with speed. As the fireman turns the crank faster, the pitch of the siren mounts higher. It is interesting to note that pitch can mount so high that our ears will cease to hear the sound—when the vibrations reach about 30,000 in one second. Also, pitch may be too low to be heard—when the vibrations are less than 16 in one second. When we sound middle C on the piano, the string struck vibrates 256 times in one second. The sound we hear when a door creaks on its hinges is caused by a vibration with a rate of about 20,000 times in one second.

Sounds may also differ in *loudness*. The loudness of a sound depends upon the amount of air that the sounding body sets in motion. If each of two strings vibrates





256 times a second, the pitch of the sound will be the same in both cases. However, one string may vibrate through a wider arc; or, its ends may be fastened to a wide board, which is made to vibrate with it. In that case a larger amount of air is set in motion and so the sound heard will be louder. High-pitched sounds can be either loud or soft, as can low-pitched sounds.

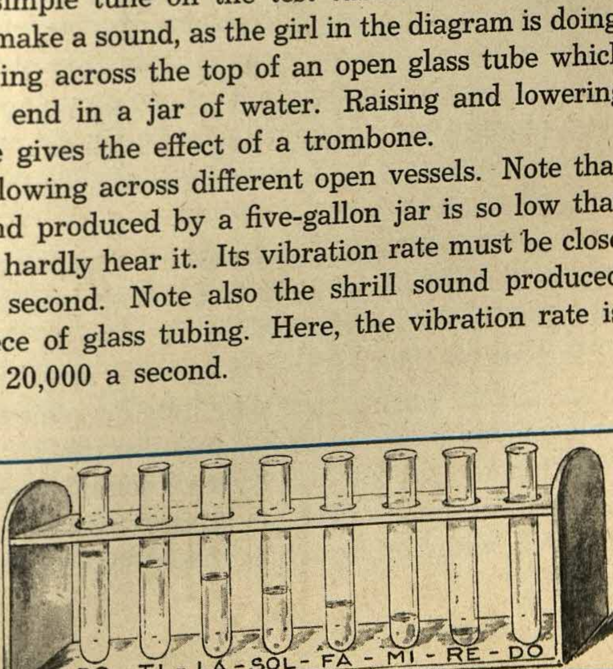
There is another difference among sounds which depends upon the kind of material that is vibrating. Also, an object can vibrate in several different ways at the same time. This gives the sound a special *quality*. It is the different quality in tones which enables us to tell the difference between a violin and a trumpet, good playing from bad, and one person's voice from that of another.

When you blow a whistle, the sound is produced, as usual, by a vibrating body; but in this case the body is the air in the tube of the whistle. That the air in almost any vessel may be made to vibrate can be seen from a number of experiments.

You can produce sounds by blowing across the top of a bottle in the way in which the boy is doing in the diagram at the top of this page. You must blow so that the stream of air coming from your mouth goes directly across the top. By pouring the proper amounts of water into eight test tubes, you can make them sound the eight tones of the musical scale. You may be able to play a simple tune on the test tubes.

Now make a sound, as the girl in the diagram is doing, by blowing across the top of an open glass tube which has one end in a jar of water. Raising and lowering the tube gives the effect of a trombone.

Try blowing across different open vessels. Note that the sound produced by a five-gallon jar is so low that you can hardly hear it. Its vibration rate must be close to 16 a second. Note also the shrill sound produced by a piece of glass tubing. Here, the vibration rate is perhaps 20,000 a second.

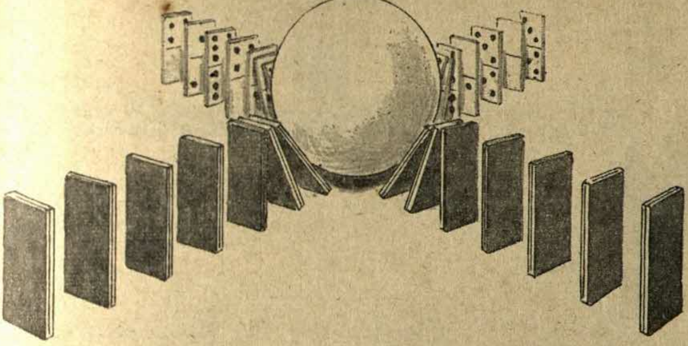

DO - TI - LA - SOL - FA - MI - RE - DO

If you can blow a bugle, bring it to class and demonstrate it to your classmates. You will note that the quality of sounds due to vibrating air columns is different from the quality of sounds caused by vibrating strings. The pitch and loudness of a tone may be the same in both a violin and a bugle, but the quality is so different that a person can hardly mistake one for the other.

How do sounds travel?

Let us refer again to the story about our imaginary rocket trip to the moon. The strangest experience we had was being unable to hear each other talk—not a sound anywhere, and for the simple reason that there is no air on the moon. Since we breathed oxygen from tanks, we were able to operate our vocal cords, but there was nothing to carry the sound from the mouth of one person to the ears of another. And so everything was silent. How very astonishing it was to see many tons of rock sliding swiftly down a steep mountainside as noiselessly as if the avalanche were taking place on the screen in a silent motion picture.

When a sounding body vibrates it must necessarily disturb the particles of air which rest against it. These particles disturb the particles of air close to them, the latter pass on the disturbance to their neighbors, and so on. Before long, air particles quite far removed from the sounding body are themselves disturbed. Try this experiment. Arrange four rows of dominoes as shown in the drawing. Tip over the inside dominoes by pushing down with a rubber ball. Each domino, in falling,

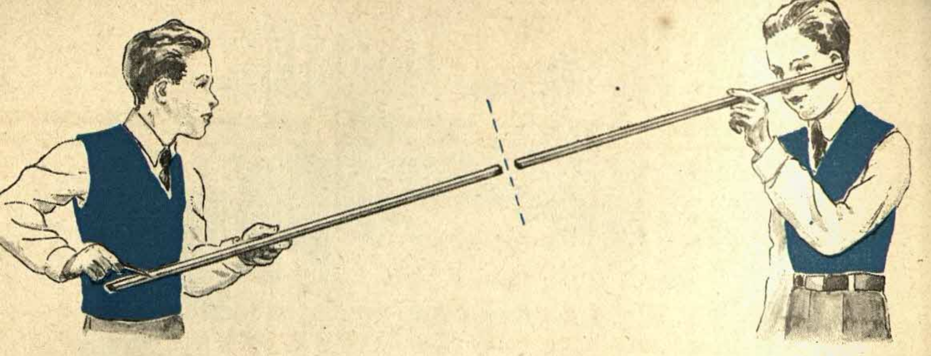


tips over its neighbor, and so on. The disturbance travels down the lines in all directions until the last dominoes fall over. If you had enough dominoes to make each row a mile long, the disturbance would travel a mile in each direction. The vibrations of a sounding body travel through the air in a similar manner. The disturbance is handed on from air particle to air particle in every direction outward from the sounding body.

You noticed that it took a few seconds for the disturbance to travel from the first dominoes to the end of each row. Similarly, it takes some time for the push given the air by a sounding body to pass from particle to particle. This is another way of saying that it takes time for sound to travel through the air.

Scientists, who have measured the speed of sound very carefully, tell us that an air disturbance produced by a sounding body travels with a speed of about 1100 feet a second. This is about 12 miles a minute.

When you see a flash of lightning, it often takes several seconds before you hear the crash of thunder. In fact, you can estimate how far away the storm center is by counting the number of seconds which elapse between



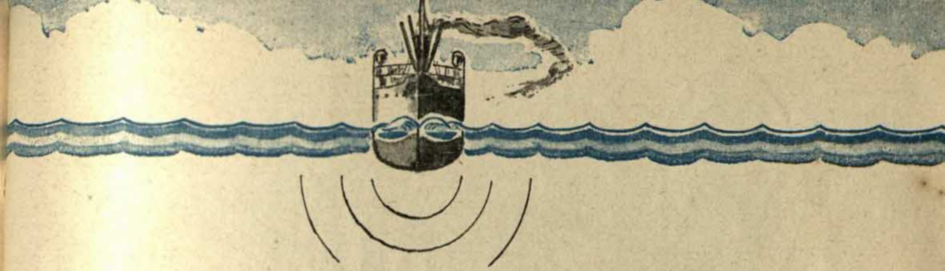
the lightning flash and the sound of thunder. If you can count five seconds, the flash occurred five times 1100 feet away, or about a mile away.

Get a long stick of wood and let your friend hold one end of it to his ear. Holding the other end in your hand, scratch the stick very gently with a pencil. Does your friend hear the sound? See how tiny a noise you must make before your friend will report that he does not hear it. Evidently, wood can carry sounds very easily.

Saw the stick into two parts. Keeping the cut ends about one-quarter of an inch apart, try the same experiment. Can your friend hear the sound? Probably not. The quarter-inch air gap is sufficient to prevent the sound from travelling through the stick. Sounds travel more easily through wood than through air.

Wood is not the only substance through which sounds can travel easily. In fact, all solid substances are good conductors of sound, though some are better than others.

We read how Indians put their ears to the ground to listen for sounds which could not reach their ears through the air. The earth, too, is a good conductor of sound. If you put your ear to a railroad track, you may be able to hear the sound of a distant train. Cer-

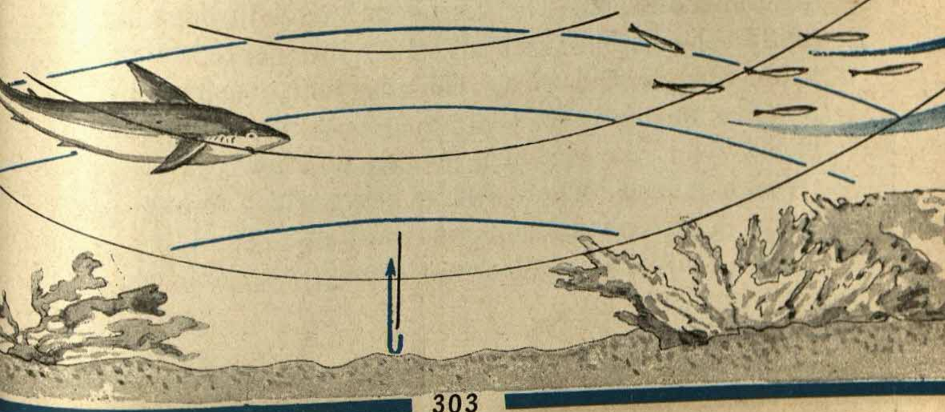


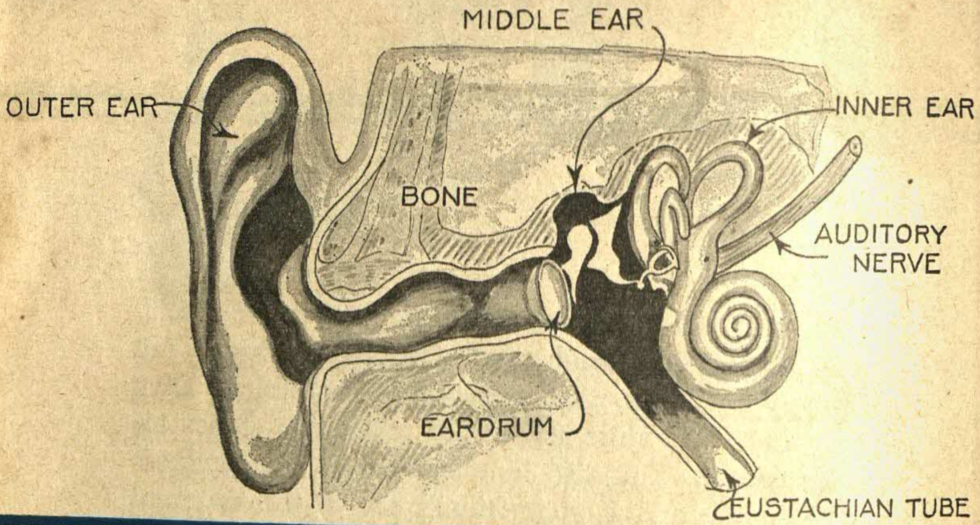
tainly steel rails are very good conductors of sound.

Among the best conductors of sound is water. Try this experiment the next time you go swimming. Dive into water, and while submerged, click two stones together gently. You will be surprised at the loudness of the sound, and if your friends are in the water at the time, they will report that they heard a loud knocking sound. Sounds made in water have been known to travel for miles without decreasing much in loudness.

How does the human ear receive sounds?

To the deaf person, there is no such thing as a sound. Air ripples strike his ear without effect. Let us study the human ear in order to find out how the air ripples, started by sounding bodies, are heard by the ear as sounds.





First, study the drawing on this page. You will notice how the ear, shaped like a horn, gathers in the air ripples caused by a sounding body. The air ripples enter the ear channel and strike the eardrum. The eardrum vibrates in accordance with the air ripples that enter it.

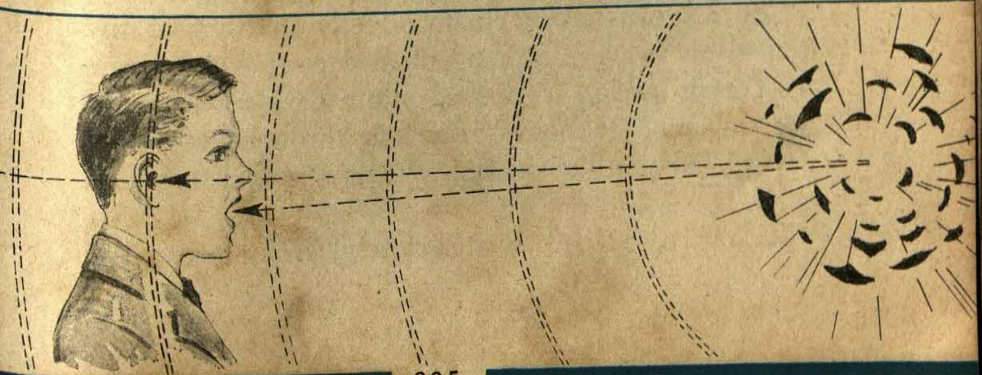
Notice, also, that the eardrum rests against a series of small bones in the middle ear. These transmit the vibrations to the oval-shaped drum of the inner ear. The inner ear is filled with a fluid and is shaped like a spiral snail shell. The vibrations travel through the fluid in the spiral. There are many tiny nerve endings in the lining of the spiral. The vibrations seem to have an effect on the nerve endings. We do not understand exactly what happens here, but we do know that these nerve endings stimulate a large nerve which enters the brain. There, the stimulus is heard as a sound.

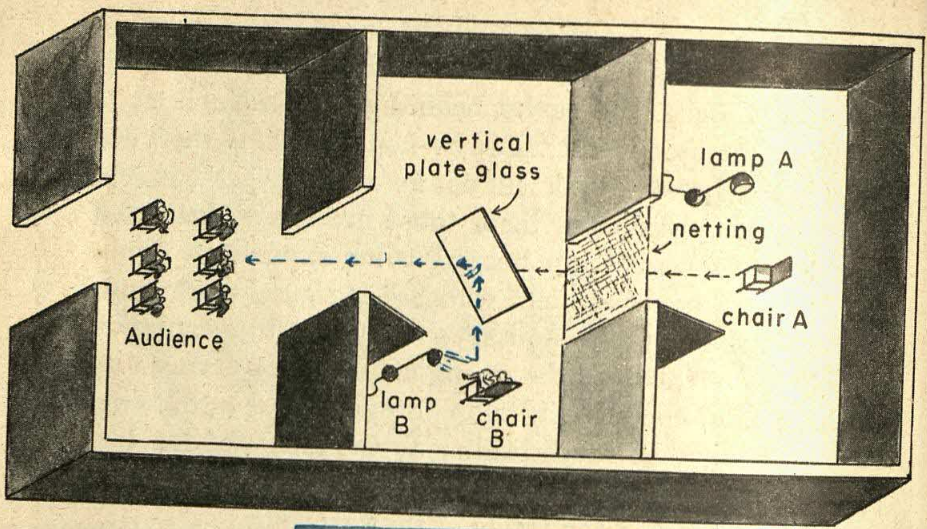
By examining the drawing closely, you will see a tube, called the Eustachian tube. There are two tubes, one leading to the cavity behind each eardrum. It is important that these tubes be kept open. If they are clogged, the eardrums will not be able to vibrate easily. When you take cold, these tubes are often obstructed with phlegm and your hearing is impaired.

It is said that soldiers who fire big guns or cannons always keep their mouths open when the explosion comes. In this way the strong air vibrations caused by the explosion can easily enter through the mouth, travel up through the tubes leading to the inside of the eardrums, and equalize in this way the pressure on the outside with that of the inside of the eardrums.

When a subway train enters a tunnel rapidly, the passengers sometimes feel the increased air pressure on their eardrums. With the eardrums pressed inward, it is difficult to hear properly, but this condition can be relieved by swallowing. The act of swallowing allows the air to enter the Eustachian tubes, so that the pressure inside the ears becomes the same as that outside.

As we go up in an airplane, the air pressure decreases. Then air inside the ears presses outward on the eardrums. Again, swallowing will help relieve the pressure.





Light for Seeing

"There is always something new at Henry's house. When we visited him the other day, he seemed rather excited. 'Wait till you see what I've got fixed up,' he kept saying. Also, he refused to let us into the room where we usually play. I noticed that the doorway to this room was draped with a heavy curtain.

"After a while, we heard Henry's father from behind the curtain saying, 'All set, now!' Then Henry got busy.

"He made us sit in chairs directly in front of the draped doorway. He then pulled a cord which drew the curtain aside. We looked into a dark room, but a doorway opposite showed some light through a mosquito netting. Behind the netting we saw Mary, sitting on a chair.

" 'Now,' said Henry, 'watch closely! When I say *three*, Mary will disappear into thin air. One–two–three!'

"To our surprise, the girl vanished, leaving an empty chair. We applauded and looked at each other in wonder. Henry bowed and continued.

" 'Thank you kindly, but watch what happens next. You all know my dog, Spot. When I whistle, Spot will appear on the now empty chair.'

"As he whistled, the shape of a dog appeared. There could be no doubt that this was Spot, for he barked and jumped off the chair.

" 'Well, what do you think?' cried Henry. 'Can you explain how it was done?'

"We tried to explain, but Henry laughed at our suggestions. Then he began to explain but confused us all the more. Finally, Henry's father joined us, much amused, and offered to clear up the mystery.

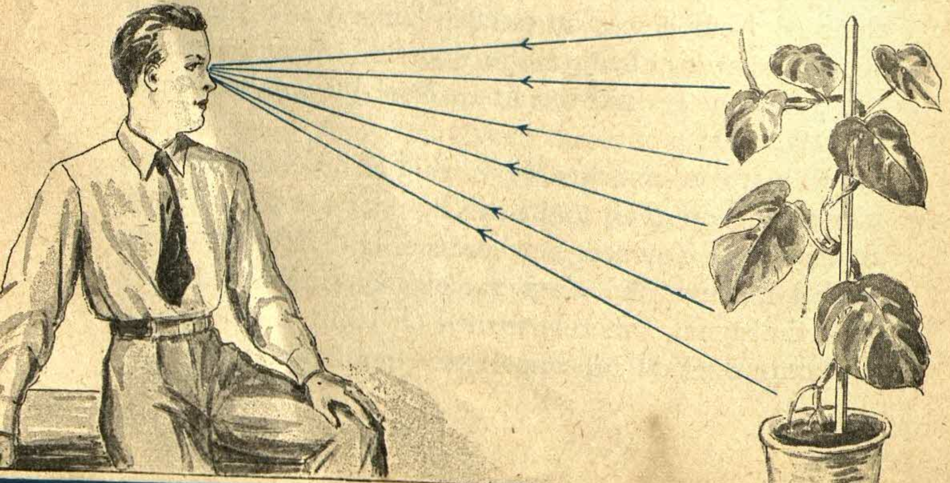
"He began by turning on the lights in the darkened room. For the first time we saw a large plate glass standing on its edge at an angle to the doorway. It was the glass which usually covers the dining-room table. In the room behind the mosquito netting we saw the chair A. Near it was an electric lamp A. To the right of the doorway, behind the door, we found another chair B, exactly like the first. Near-by was a second lamp B.

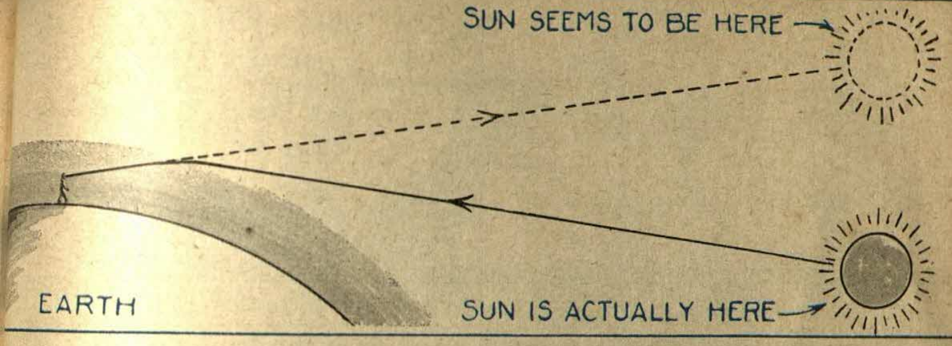
" 'When you first saw Mary,' said Henry's father, 'she was sitting on chair A in the light of lamp A. Lamp B was dark. You saw her because light from her body passed through the glass to your eyes. When Henry gave the signal, I merely turned off lamp A and turned on lamp B. You no longer saw her because no light could come from her to your eyes. Instead, the light from the empty chair B struck the glass. The glass acted like a mirror, shining the light from chair B into your eyes. Since the chairs are exactly alike and very carefully placed, you were really seeing chair B, but you thought it was chair A. In the meantime, and in the dark, Mary had given her seat on chair A to Spot. When Henry whistled, I turned off lamp B and put on lamp A again. Then you saw Spot on chair A. Simple, isn't it!' "

When do we see an object?

It is true that our eyes may deceive us, but it is also true that our eyes will not *see* unless light comes to them. No animal can see in the dark if the darkness is complete. Certain animals, like the cat and the owl, have eyes that are more sensitive to light than our own. They can, therefore, see objects that give off only small amounts of light.

When you first enter a motion picture theater, it seems pitch dark; you may stumble over seats and grope your



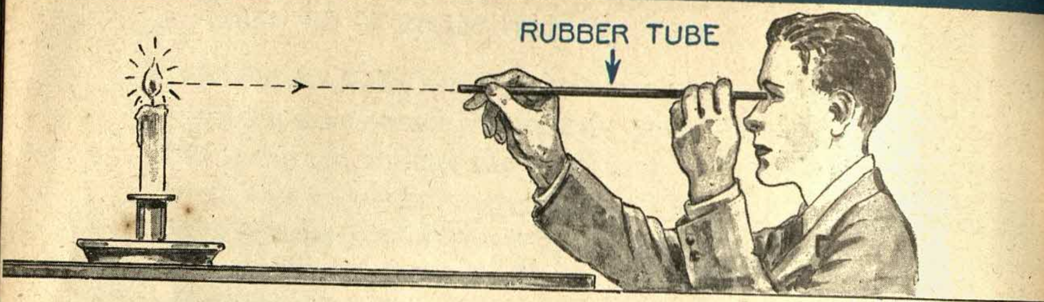


way until an usher comes to your rescue with a flashlight. After you have been seated for a while and your eyes have been accustomed to the dim light, you begin to see many objects. You wonder how you could have been so "blind" when you came in. Yet, if all the exit lights, musician lights and screen light were to be extinguished, you would be able to see nothing, no matter how long you remained in the theater. Without light one cannot see. Unless light from an object enters the eye, the object cannot be seen.

In what different paths may light travel?

When a ray of light leaves the sun, it travels through space in a straight line until it reaches the earth's atmosphere. If the direction of the ray is toward the center of the earth, the light will continue through the atmosphere in a straight line. Otherwise, the ray is bent by the air as shown in the diagram. This is due to the air's increasing density as a ray travels from outer space and strikes the surface of the earth obliquely.

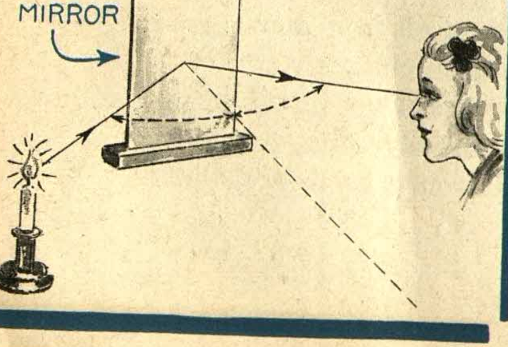
Near the surface or at any given level in the atmosphere, the density of the air usually stays about the same while a ray is travelling through it. Hence, while

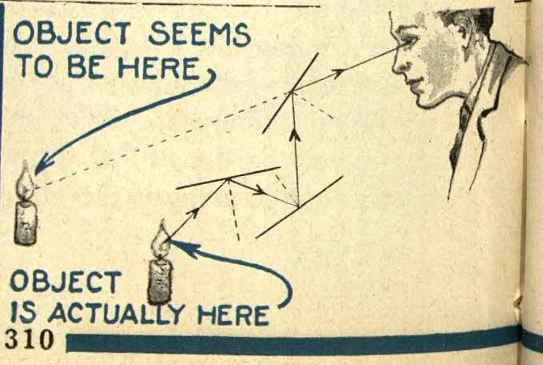


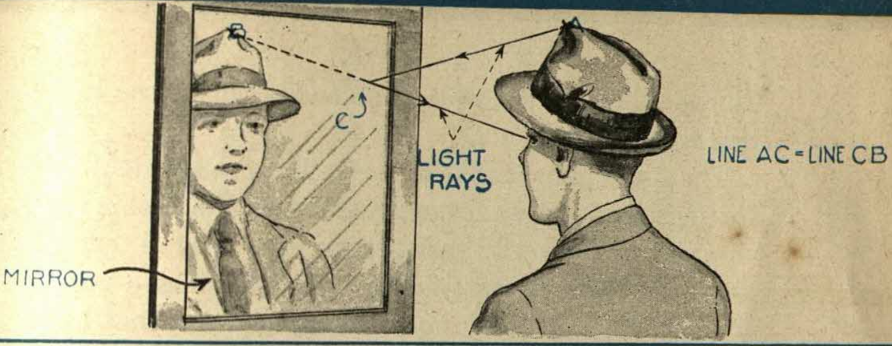
passing through any one layer of air of the same density the ray travels in a straight line. If you try to see a candle flame through a piece of rubber tubing, it will be necessary to hold the tubing in a straight line before you can see the flame.

When a ray falls on a smooth surface, the direction of travel may change, especially if it strikes the surface at an angle. Rays falling perpendicularly on a smooth surface will bounce back in the direction from which they came.

When the eye sees an object, the object appears to be at the end of the direct ray which enters the eye, and to the eye, the ray seems to be a straight line. This is so no matter how curved or broken is the path which the light travels between object and eye. Study the drawing below. By means of the mirrors, light rays from the candle are made to travel the broken path, as,







indicated, before it enters the eye. The candle will be seen at a point which is at the end of a straight line that is just as long as the broken line. The direction of that straight line is the last direction of the light before entering the eye.

As you stand before a mirror looking at the hat on your head, a ray of light from the hat reaches your eye. The path, however, is a broken one as shown in the drawing. Nevertheless, the eye sees this path as one straight line. Point A of the hat appears to be at point B and the whole hat is seen to be in back of the mirror. The image of an object seems to be as far in back of a plane mirror as the object is in front of it.

How fast does light travel?

The light which leaves the sun travels at the great speed of 186,000 miles a second, but the sun is so far away that it takes 500 seconds or about 8 minutes for the light to reach the earth. This is a tremendous speed—fast enough to travel more than seven times around the earth in one second. Some years ago, a scientist measured this speed in a series of experiments which lasted several years and cost thousands of dollars.

The speed of 186,000 miles a second is very close to his best calculation.

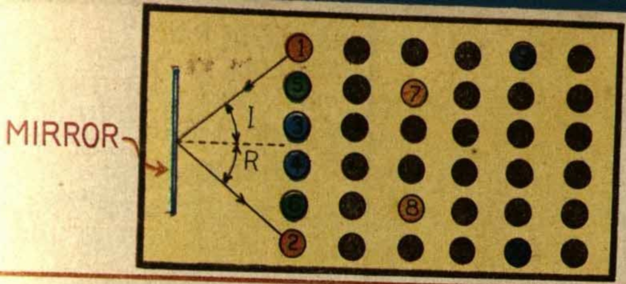
The speed of light has made possible a convenient unit for measuring great distances, such as the distance to the stars. When the astonomer says that a certain star is 1000 light-years away, he means that a ray of light would take 1000 years to travel from that body to us. If you wish to know how many miles that would be, calculate the number of seconds in 1000 years and multiply the result by 186,000. You will find the product to be about 5,870,000,000,000,000 miles. There are stars even farther away.

How may light be controlled with mirrors?

We have already learned that a ray of light will change its path when it strikes a smooth surface. That is what happens when light falls on a mirror. In the story on page 306, describing how Henry entertained his friends, the smooth surface of the plate glass changed the direction of travel of the rays of light. The smoother the surface, the better is the reflection.

The surface of water is an excellent reflector of light. When a glass of water is standing in the sunshine, it is almost as good as a mirror for reflecting the light to the ceiling. As you disturb the glass and roughen the surface of the water, the reflection on the ceiling decreases in brightness. When the surface of a lake or an ocean is calm, the light from the blue sky is reflected to your eyes. That is why the lake or the ocean appears blue.

The circles shown in the drawing on page 313 repre-



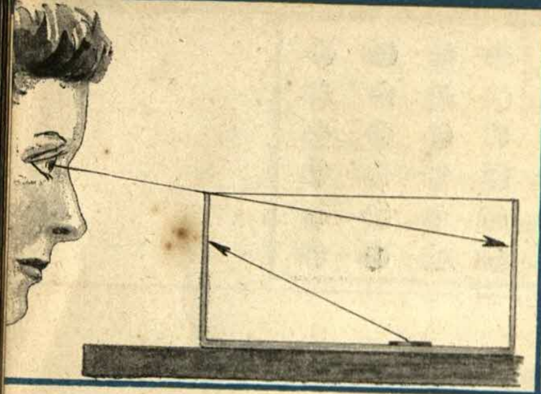
sent the pupils in a classroom. Fasten a large mirror to the blackboard. With a piece of chalk draw a line on the floor, perpendicular to the front wall at a point directly under the middle of the mirror. Now ask pupil No. 1 to say which of his classmates he sees in the mirror. He will probably see No. 2, who will also see him. Draw chalk lines on the floor from No. 1 and No. 2 to the point where the perpendicular line meets the front wall. Compare the two angles that are shaded in the drawing. Are they about equal? Do the same for pupils 3 and 4; 5 and 6; 7 and 8; 9 and 10.

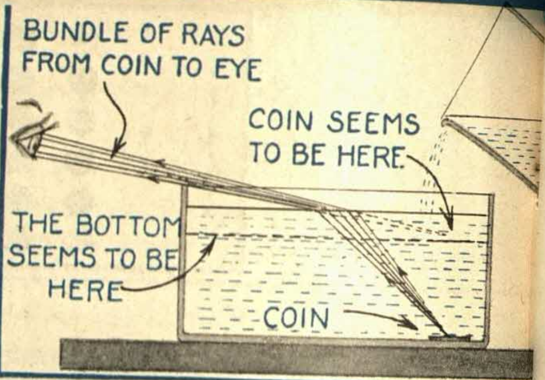
When No. 1 sees No. 2, a ray from No. 2 strikes the mirror and is reflected to the eyes of No. 1. In this case, the angle marked I is called the *angle of incidence.* The angle marked R is called the *angle of reflection.* The two angles are equal. This is known as the *law of reflection.*

How may light be controlled with lenses?

In order to understand the answer to this question, we must first see what happens to rays of light as they travel from air into and out of a dense substance like glass or water.

Place a coin at the bottom of an empty pan. Shut





one eye and look at the coin obliquely across the upper rim of the pan. Lower your open eye until the side of the pan just hides the coin from sight. As you keep your position fixed, have a friend pour water into the pan. An inch or two of water brings the coin into view. Now, since we never see an object unless light from that object reaches the eye, the coin must be sending a ray of light to the eye. This ray could not have travelled in a straight line, because a straight line between coin and eye is stopped by the side of the pan. From other experiments, we know that this bending takes place at the surface of the water. It is there that the ray passes from water into air. You may observe that the entire bottom of the pan seems to rise when looked at obliquely, so that the depth of water seems less than it really is.

To understand this, carefully read again page 310. There you learn that when we see an object, the object seems to be at the end of the ray which it sends out. Also, the eye sees this ray as a single straight line. In the drawing, you see the actual path traversed by a ray from a point A on the bottom of the pan to the eye.

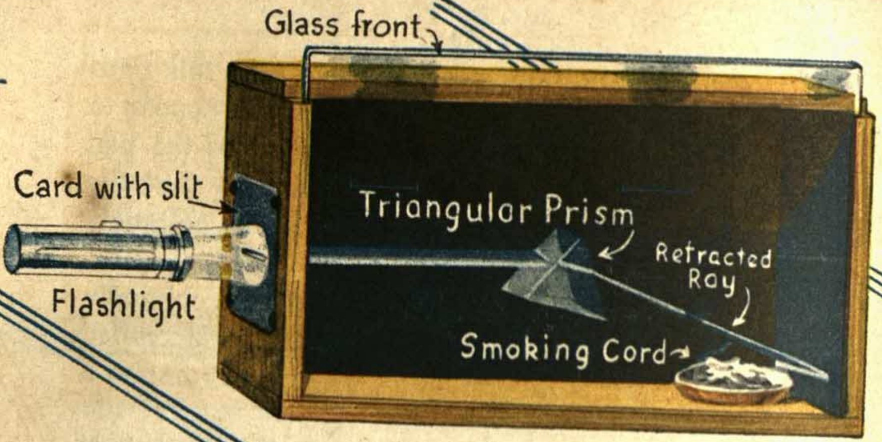
This is a bent path. However, the eye sees this path as a single straight line. Hence, point A will appear to be at point B—similarly, every other point of the pan bottom seems higher than it was before, so that the entire bottom seems to rise when looked at obliquely through water.

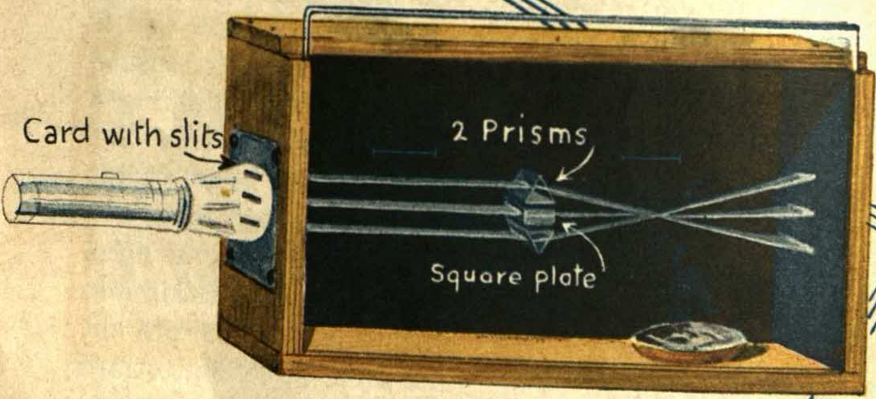
The bending of a ray of light as it passes obliquely from one transparent substance into another is called *refraction.* There is no refraction when a ray enters a transparent substance perpendicularly.

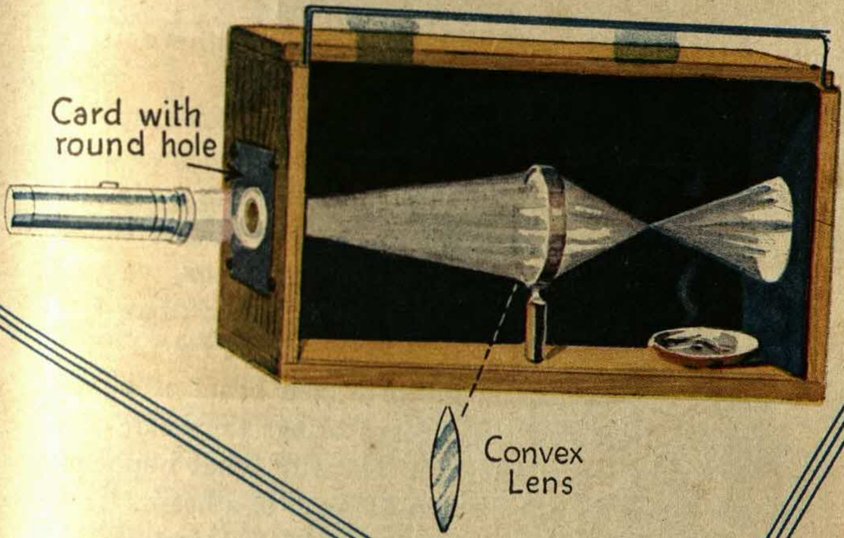
A good way to study the behavior of light rays is to build a light box, such as the one shown on page 316. The box has a glass window on one side. The opposite side is covered with black cloth in which there are two slits. Through these slits, one may insert the hands for holding the various objects shown. At the side is a flashlight aimed at a slit in the side of the box. Inside, standing on the bottom, is a small dish containing a burning piece of cord which fills the box with smoke. The smoke helps to make the flashlight beam visible through the window, when the room is darkened.

Now, hold a prism in the path of a beam of light. See how the beam is bent when passing from air into glass and bent again when passing from glass into air. Note that it is bent twice in the same direction, toward the base of the prism.

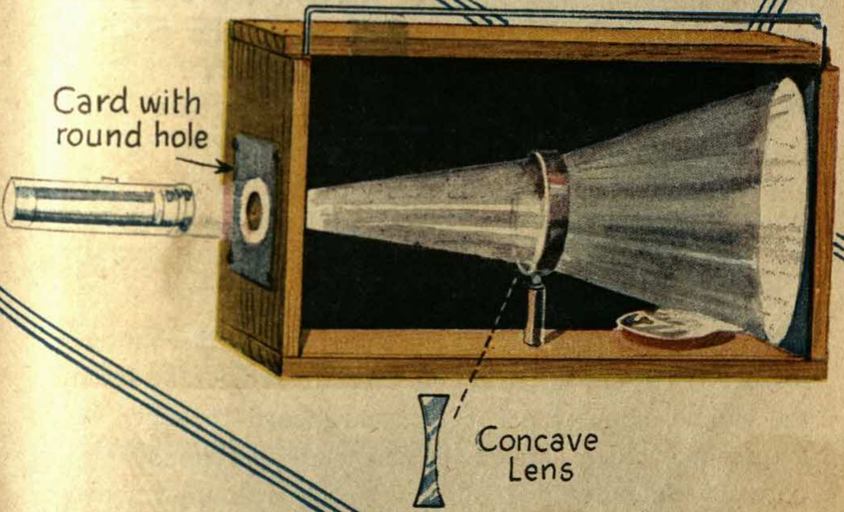
Replacing the single slit on the side of the box with a triple slit, hold two prisms and a square plate in the path of the three rays, as shown. The upper ray bends downward, the middle ray goes through without any bending at all and the lower ray bends upward. The


Glass front
Card with slit
Triangular Prism
Refracted Ray
Flashlight
Smoking Cord


Card with slits
2 Prisms
Square plate



Card with round hole
Convex Lens



Card with round hole
Concave Lens

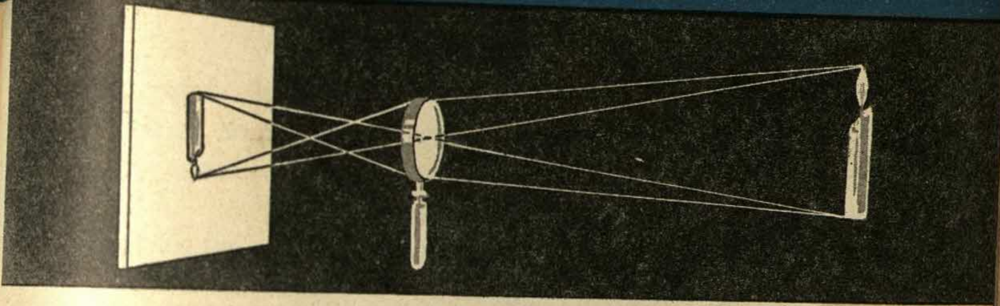
three rays which come out cross at one spot. We call this spot the *focus.*

A glass lens may be considered as being made up of a series of glass prisms, around a centerpiece that has parallel sides. If the prisms are placed base to base, we get a convex lens, one whose center is thicker than its edges. If the prisms are placed apex to apex, we get a concave lens, one whose center is thinner than its edges.

Hold a convex lens in the path of a beam of light, as shown. Note how such a lens brings the beam together at the focus. Contrast this with what happens when a concave lens is held in the path of a beam. The concave lens spreads out the beam. Try to measure the distance between the point at which a convex lens focuses a beam of parallel rays and the center of the lens. This distance is called the *focal distance.*

Light from the sun can be bent by a convex lens so that the rays come together at a point. This point, when examined carefully, is really a small circle. It is an image of the sun. With objects not so far away as the sun, it is possible to focus images that can be recognized more easily. Try this experiment.

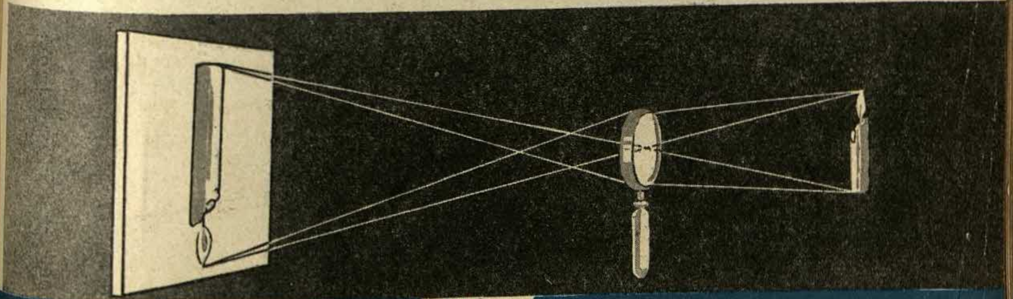
Stand a lighted candle on the table. Draw the shades so that the room is darkened. About three feet from the candle, support a sheet of cardboard to serve as a screen. Hold a convex lens near the screen, in the path of the candle rays, and move the lens slowly toward the candle. Stop moving the lens when a sharp image of the candle is visible on the screen. The image is smaller than the candle itself, and is inverted. The



inversion is due to the fact that the rays coming from the top part of the candle cross those coming from the bottom of the candle. The size of the image depends on how far away from the lens you place the candle. The farther away the object is from the lens, the smaller is its image when focused. That is why an image of the sun, which is 93 million miles away, is so small that it seems to be practically a point.

The camera lenses act like a convex lens. The object whose picture is taken is usually six or more feet away from the lens. Hence the image focused on the film is small and inverted. The more distant the object, the smaller is its picture (image) when focused.

We saw that the image of the candle focused on the screen was larger when the lens was nearer the candle. In a certain position of the lens and the candle the focused image is the same size as the candle. In this case, the lens is just as far from the screen as it is from

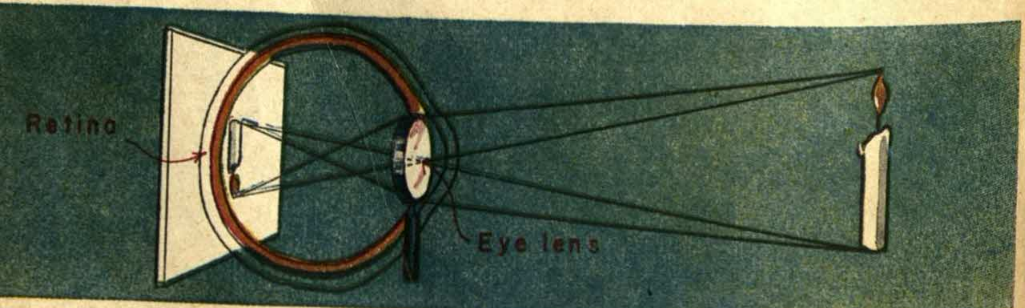


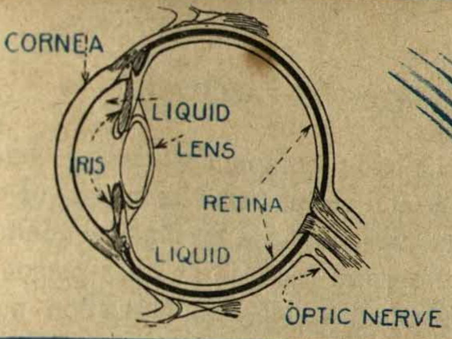
the candle. If you now move the lens still closer to the candle, you will need to move the screen farther away in order to focus the image on it. The image will be larger than the object, and inverted.

If you view the candle through the lens when the latter is at less than its focal distance from the candle, you see an enlarged and upright candle. Look also at your finger or a page of print through a convex lens held at less than its focal distance away. Again you see the finger or the print much enlarged and upright. You are using the lens as a magnifier or as a reading glass. This is the idea on which the simple microscope is based.

How do we see with our eyes?

In the eye, a convex lens forms an image of the object that is seen. On page 321, you see a diagram of the human eye. After passing through the cornea and the pupil, the light is focused by the lens as a small, inverted image on the retina. The latter is sensitive to light; it is stimulated by the image. The stimulus is carried by the optic nerve to the brain. There, by a process which we do not fully understand, the stimulus is changed to the sensation that we call seeing.





If the cornea, lens or eyeball changes shape, or if the eye muscles controlling the lens curvature have ceased to work properly, vision becomes defective. Images are no longer focused on the retina, but in front of it or in back of it. The nearsighted eye has a cornea or lens which is so convex that images come to a focus in front of the retina. To correct this difficulty, an eyeglass that is concave is placed in front of the eye. The eyeglass corrects the effect of the overly convex cornea and eye lens. Thus, images are focused sharply on the retina. The farsighted eye has a cornea or lens which is not convex enough, so that images focus somewhere in back of the retina. In order to correct this difficulty, an eyeglass that is convex is placed in front of the eye. The convexity of the eyeglass, together with that of the cornea and eye lens, causes images to be focused sharply on the retina.

Frequently, the cornea may be so distorted that an eyeglass must be especially ground to make up for these distortions. A person with astigmatism usually has eyes that are distorted in this way. If eyeglasses are correctly fitted and properly used, such eye defects will not be troublesome.

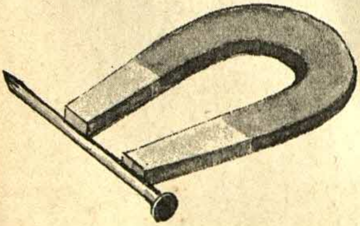
Messages by Electricity

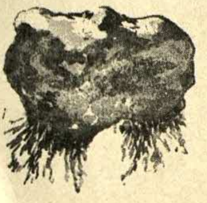
In the two preceding chapters, we have learned how hearing and seeing serve as means of communication. When a person speaks, mechanical energy is transferred from his vocal cords to another person's ears. Seeing makes one kind of communication possible, because whenever we *see* an object, such as a book, light energy travels from the object seen to the eyes of the one who does the seeing. But there are means of communication in which another kind of energy is transferred from one person to another or from one place to another. We refer to electrical energy. The modern world makes great use of the telegraph, the telephone and the radio. Television is being more widely used every day. In each of these methods of communication, electricity plays an essential part. In this chapter we shall deal with some of the simple ideas which make possible the sending of messages by electricity.

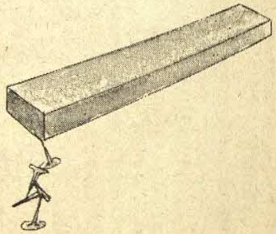
What have we learned about magnets?

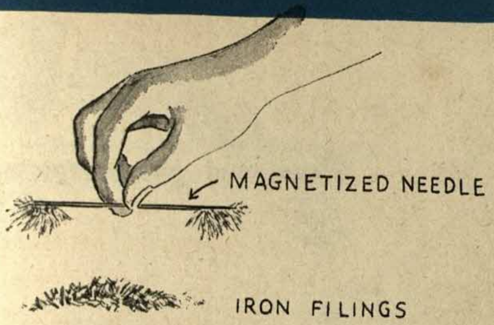
Any study of electricity must begin with a study of magnets. In your science work of earlier grades, you learned a good deal about magnets. Let us recall some of this knowledge by listing a few of the important ideas.

1. *Magnets are pieces of iron, iron ore, steel or various alloys that can attract other pieces of iron.*

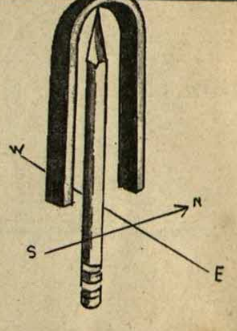






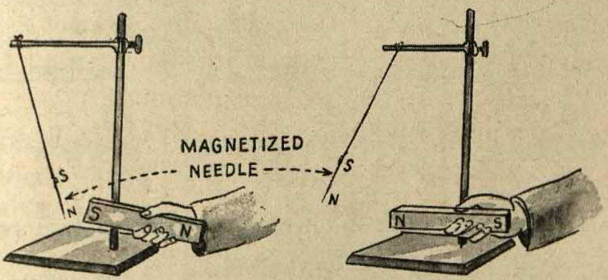


2



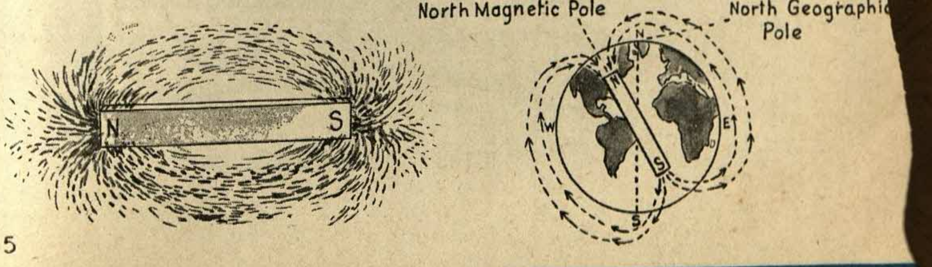
3

2. *The ends of a magnet, called the poles, attract more strongly than other parts.*
3. *A freely suspended magnet will point approximately north and south.*

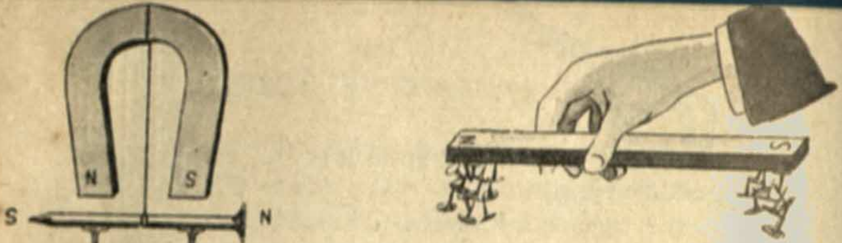


4

4. *North-seeking poles or south-seeking poles repel each other; a north-seeking pole and a south-seeking pole attract each other.*
5. *The planet on which we live acts like a magnet.*

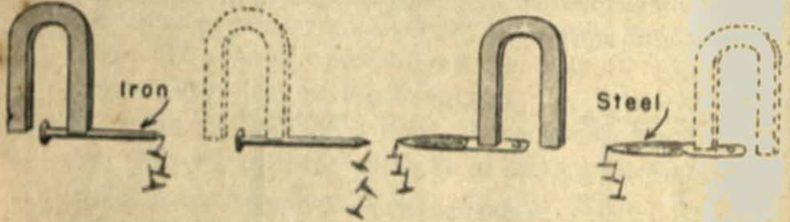


5

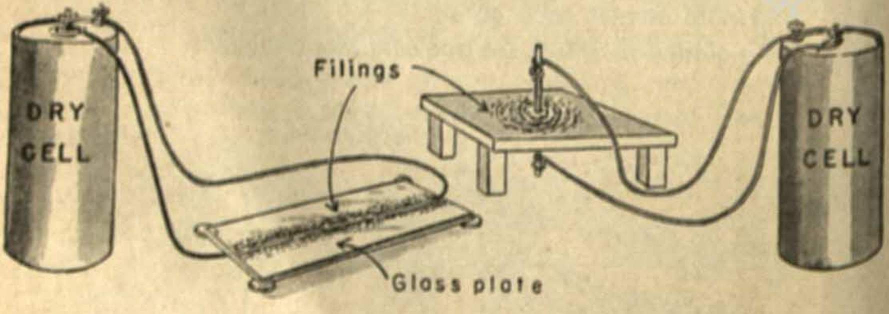


6

6. *A piece of iron that is held near, or rubbed on, a magnet becomes magnetized.*

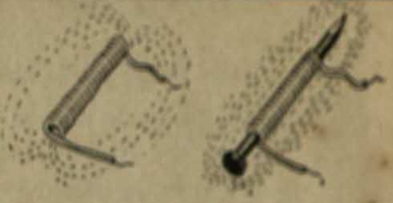


7. *Soft iron loses its magnetism quickly; steel retains its magnetism for a long time.*
8. *A wire through which electricity is flowing behaves like a magnet.*

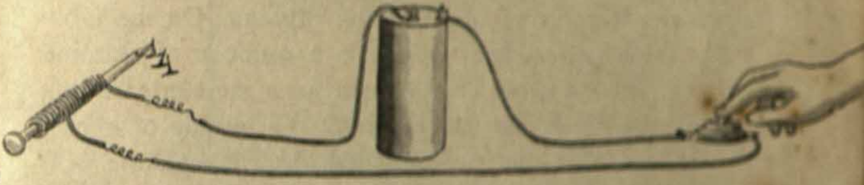


8

9. *When the wire is made into a coil, the magnetism is concentrated.*

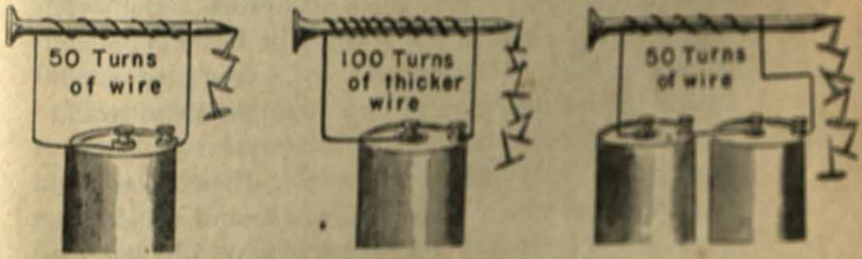


9



10

10. *When a piece of iron is placed inside the coil, the iron becomes a magnet.*



11

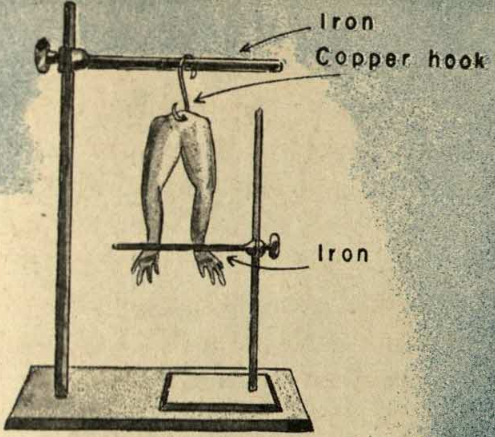
11. *An electromagnet can be made stronger by increasing the number of turns of wire or by increasing the amount of electricity.*

In the last four of these ideas about magnets, we find that magnetism and electricity are closely related. In fact, the strongest magnets are made by using electrical energy. This brings us to an important question.

How do we make electricity flow?

The story is told of an Italian scientist—Galvani was his name—who by accident came upon a fact which opened to the world a new field for study. Galvani was experimenting with an electric machine, the kind in which electricity is produced by rubbing. On the table at which he worked were also a number of skinned frogs. He went out of the room for a moment, leaving the knife with one end touching the muscle of a frog and the other end touching his electric machine. On returning, he saw the frog's leg under the knife twitching and jerking as though it had come to life. He was astonished. He tried another frog's legs. The same thing happened. Knowing about Franklin's kite experiment, he stretched a long wire from the roof of his house to a distant tree and connected one end of his aerial wire with a freshly skinned frog's leg. The latter he stuck on an iron railing. During a storm the frog's leg would twitch. Sometimes even in clear weather there would be the same twitching, but long intervals would pass during which no twitching was visible. Then it occurred to him to touch the copper wire, one end of which was in the frog's leg, to the iron railing to which the leg was fastened. To his surprise the leg jumped every time he brought the copper and iron together.

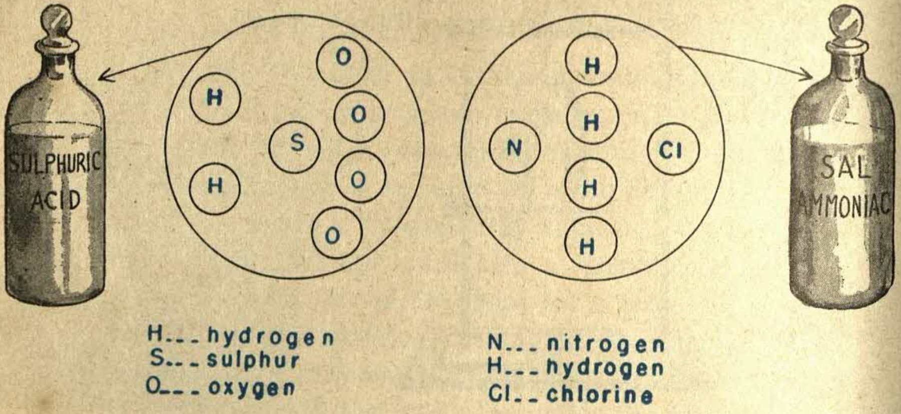
Galvani wrote about his experiments and gave some interesting explanations of why the frog's legs jumped. Another Italian scientist, Volta, was very much interested in the "galvanized" frog's legs and performed some experiments of his own. He found that three substances were essential; namely, copper, iron and the fluid in the



muscular tissue of the frog's leg. He really did not know what was happening inside the frog's muscle, nor did he know why; but he made a brilliant guess. "The two metals and the fluid are undergoing a chemical action," he said, "a chemical action that produces an electrical force."

Thus was born the idea that electricity can be made to flow by chemical action. Volta's next step was to try other metals and other fluids. He obtained the best results with zinc, copper and acids. Since his time, we have found other substances that work even better; but all of our modern batteries are based on Volta's principle. The world honors Volta by using his name as a unit of electrical measurement. You have all heard of the *volt.*

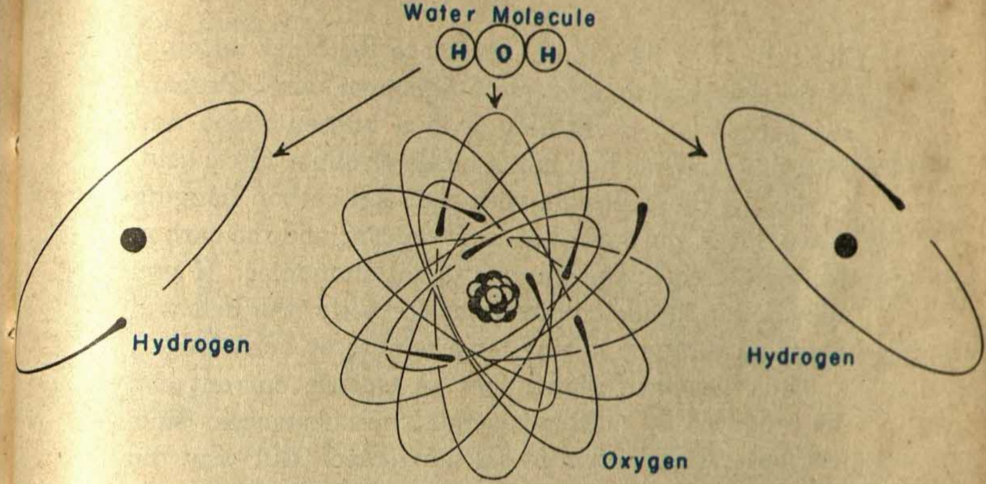
Now, the difficult thing to understand about Volta's cell is why a chemical action should cause electricity to flow. It probably puzzles you and it certainly puzzled Volta himself. Volta could offer no satisfactory explana-



tion. Since his time, many answers have been given, each one better than those that preceded it. Today, scientists explain the action in a cell in terms of an idea called the Electron Theory. It is the best answer to the puzzling question which has yet been given, and we believe that any boy or girl can understand it if he or she will read carefully, think hard and ask questions. The theory begins with a few important ideas.

All substances are made up of tiny particles called atoms. Thus, in Volta's cell the zinc plate is made up of zinc atoms, the copper plate of copper atoms, and the diluted acid is made up of several different kinds of atoms.

Substances are different from one another because they contain different atoms. Thus, sulphuric acid contains two atoms of hydrogen, one atom of sulphur and four atoms of oxygen. Sal ammoniac contains one atom of nitrogen, four atoms of hydrogen and one atom of chlorine.



Atoms are made up of three kinds of tiny particles. In the center of the atom there is a cluster of particles called the nucleus. Some of these particles are protons, which have positive electrical charges. The other particles are neutrons, which have no charge. Outside the nucleus there are electrons, which have a negative electrical charge. Electrons travel in orbits around the nucleus. The electrons are the only particles easily detached from an atom.

Electrons are bits of electricity. Thus, matter is really electricity and electricity is matter.

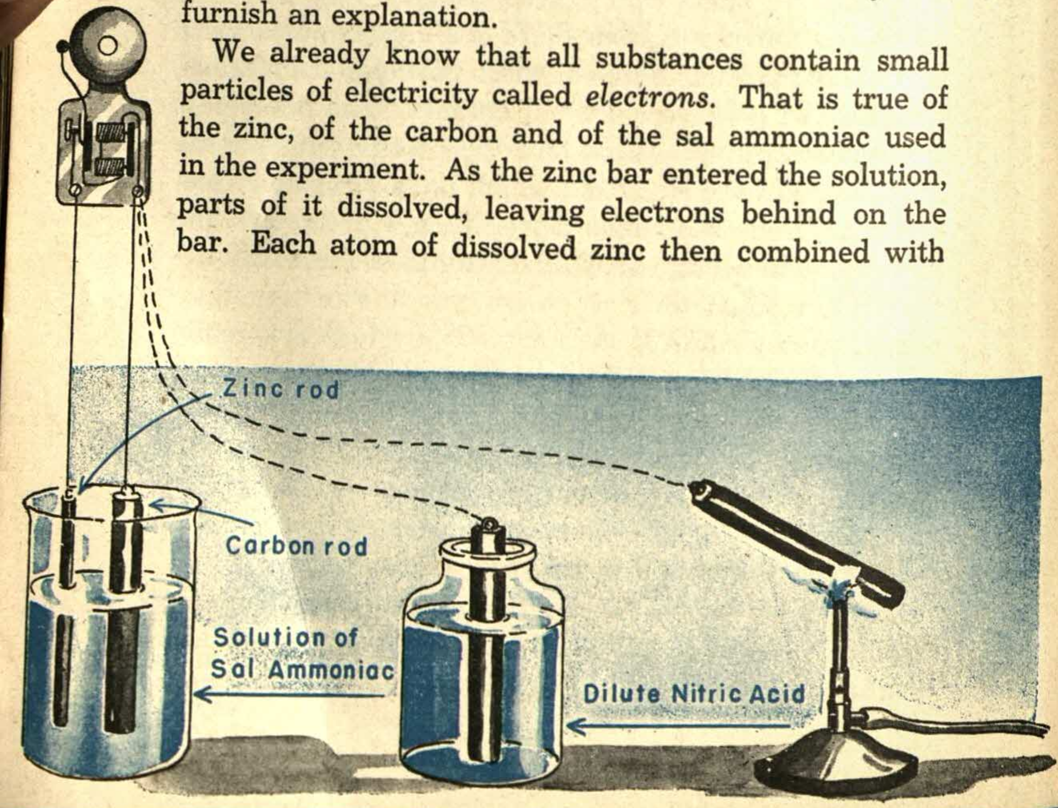
In the experiments of Galvani and Volta, certain substances were put together in order to produce an electric current. Let us perform an experiment of our own in which we put together certain substances.

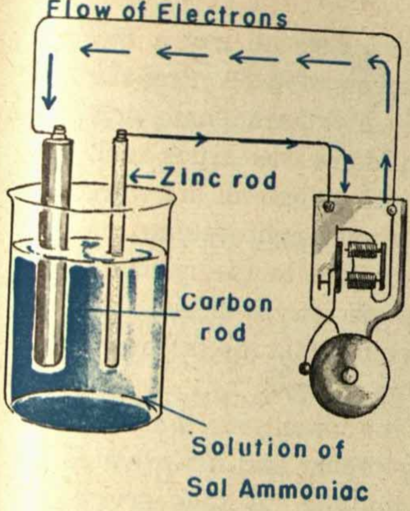
Dissolve three tablespoonfuls of sal ammoniac in a small jar of water. Tie a zinc bar to one terminal of a lightweight electric bell with copper wire. Make sure that the bell works by testing it with a good dry cell. Now tie a rod of carbon to the other terminal of the bell with another piece of copper wire. Prepare the carbon rod by heating it in a bunsen flame and plunging it, while hot, into a bottle of dilute nitric acid.

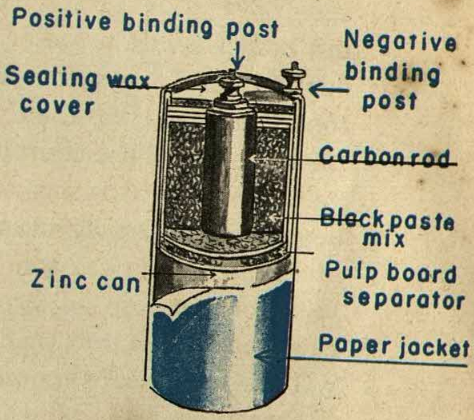
Holding the bell high, with zinc and carbon hanging down, lower the apparatus until the zinc and the carbon are immersed in the solution of sal ammoniac. If you have followed all the directions correctly, the bell will ring and continue to ring for a minute or even longer.

Thus, we have shown that an electric current can be produced by putting together the substances: zinc, carbon and a solution of sal ammoniac. But why did this happen? Let us see how the electron theory can furnish an explanation.

We already know that all substances contain small particles of electricity called *electrons*. That is true of the zinc, of the carbon and of the sal ammoniac used in the experiment. As the zinc bar entered the solution, parts of it dissolved, leaving electrons behind on the bar. Each atom of dissolved zinc then combined with







DRY CELL

other atoms in the solution. When this chemical action took place, hydrogen atoms were set free at the carbon rod. Electrons did not accumulate on the carbon because it did not dissolve.

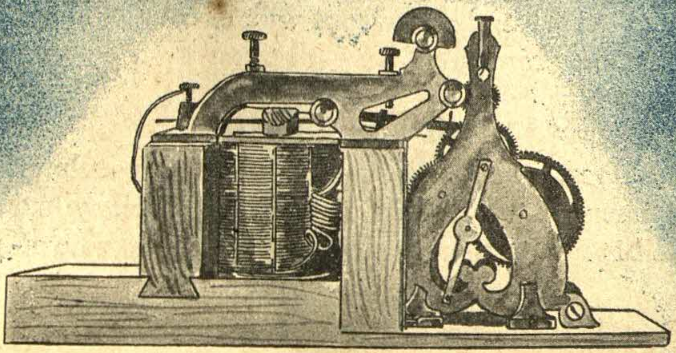
As a result, the zinc bar was left with many electrons in excess of its normal number. Over the copper wire path that had been provided, the excess electrons flowed from the zinc to the carbon, ringing the bell as they passed through it.

In such a case, the movement of electrons from the zinc to the carbon is an electric current. If part of the path is a coil of wire, the electrons will, of course, make this coil an electromagnet.

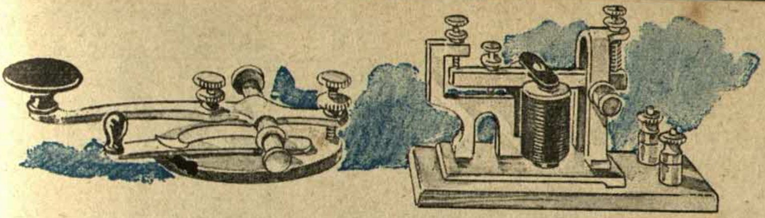
How do we send messages by telegraph?

Samuel Morse was an artist—a painter and a sculptor of prominence. In 1832, shortly after Joseph Henry had exhibited his famous electromagnet, Morse was returning home from Europe. On board ship he met a Dr. Jackson, who engaged him in conversation. Among the topics discussed was the electromagnet and its behavior. In the course of the conversation Morse was struck with an idea. From that moment on, his talents in art were devoted to sketching ideas for a telegraph system. As he landed in New York, he remarked to the captain: "Should you hear of the telegraph one of these days as the wonder of the world, remember that the discovery was made on board the good ship *Sully.*"

Five years later Morse filed his patent for the telegraph; he had given up his art forever and his private fortune had been reduced to nothing. It took seven years more of great effort in the face of ridicule, poverty and discouragement of all kinds before he perfected his device. Finally, in 1844, Morse successfully sent a message from the Capitol in Washington to Baltimore. This famous message, "What hath God wrought!" marks the birth of the telegraph. When he died in 1872, Morse was a rich and prominent man. The country was covered with a network of telegraph wires carrying mes-



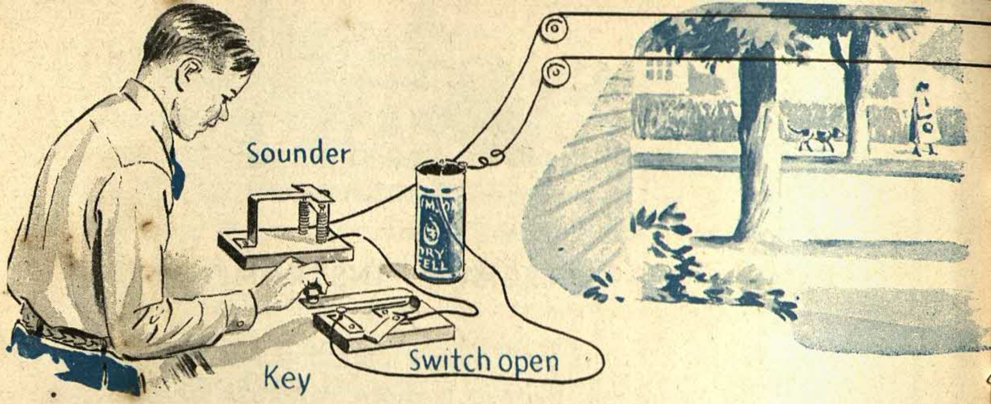
Morse's
Telegraph



sages from city to city. He gave mankind an invention which many people believe is more valuable than any paintings that he might have left, had he continued in his earlier career

You have probably made simple telegraphs out of electromagnets, in your science work in earlier grades. You may wish now to make a better one, based on the model shown on page 334. Go into partnership with a friend or a classmate and have him make one, too. Connect your instruments as shown in the drawing. The wires leading from one set to the other may be long. The stronger the current and the more wire you use in winding the electromagnets, the better this telegraph will work.

Before you can send messages to your friend, he must close his switch. The only break in the circuit is your own switch or sender. When you press it, the current flows through your set and also through his set. The electromagnet, or sounder, in each set will attract the iron strip poised over it and draw it down upon the nail with a click. When you release your sender, the magnetic attraction will disappear and the strips will spring back. In a real sounder, a spring usually helps to pull back the iron strip. The clicks and the intervals



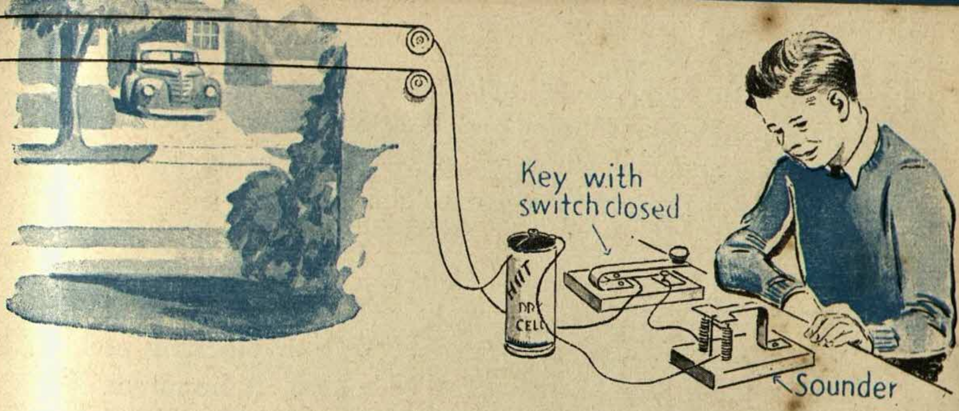
between clicks are translated by the listener into letters, words and sentences.

To listen to your friend's message, you must keep your sender closed and let him make and break the circuit. Of course, in order to understand each other, you must invent a language or a code. When Morse invented the telegraph he also invented the Morse Code. If you find the Morse Code too difficult to learn quickly, try the scheme shown in the chart below. For example, if you wish to send the letter "L," click twice, pause, and then click three times, since "L" is in column 2 and row 3.

How do we send messages by telephone?

In 1870 the telephone was only an idea in the mind of the young dreamer, Alexander Graham Bell. In 1875

0	1	2	3	4	5
1	A	B	C	D	E
2	F	G	H	I	J
3	K	L	M	N	O
4	P	Q	R	S	T
5	U	V	W	X	Y
6	Z				

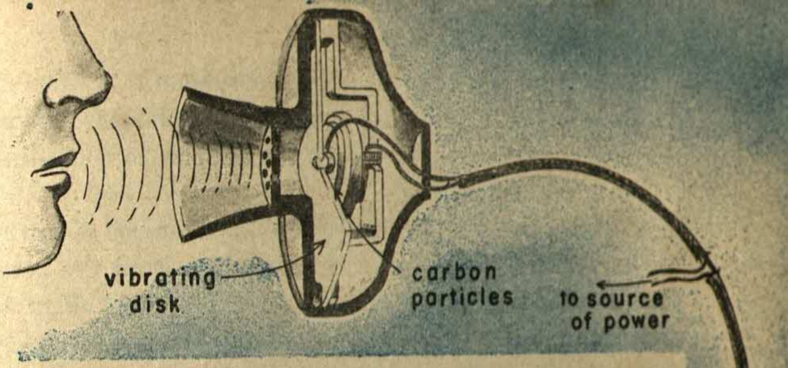


it had become an experiment in the laboratory. In 1877 the experiment was being shown as entertainment in theaters. In 1880 it was a useful device in 30,000 homes and offices. In 1928, 23 billion messages were sent by telephone in the United States alone. Today it takes over six million telephone directories each year to supply the people who use telephones. We could not carry on civilized living, as we know it, without this invention.

The history of the telephone is one of the most fascinating stories of science. Bell and his assistant, Watson, were working one hot afternoon with a device known as a "harmonic telegraph." Bell's idea was to perfect a system of telegraphy by which many messages could be sent over one wire at the same time. The device had been giving them trouble for months. Without much interest Watson adjusted the vibrators in the attic as Bell tuned his in the cellar. At this moment an accident occurred. The contact screw on one of Watson's vibrators melted fast to the vibrator because of the heat of the electric spark. This enabled a continuous current to flow through the coil and the stage was set because a magnet happened to be near the coil. Watson reached out to pluck the vibrator loose. When he did so he moved a magnet in the presence of a coil.

Suddenly Watson heard a shout. Bell came dashing up the steps, excited and yelling, "What did you do then? Don't change anything! Let me see!" Bell had heard in the cellar the sound of Watson plucking at the vibrator. The telephone had been born. In hundreds of ways Bell and Watson repeated the experiment, and with greater and greater success. It was not long after this that the first words ever spoken over a telephone were heard by Watson. They were, "Mr. Watson, please come here. I want you." In 1915 Bell, in Arlington, Virginia, spoke the same words over the telephone to Watson, in the Hawaiian Islands, 5000 miles away.

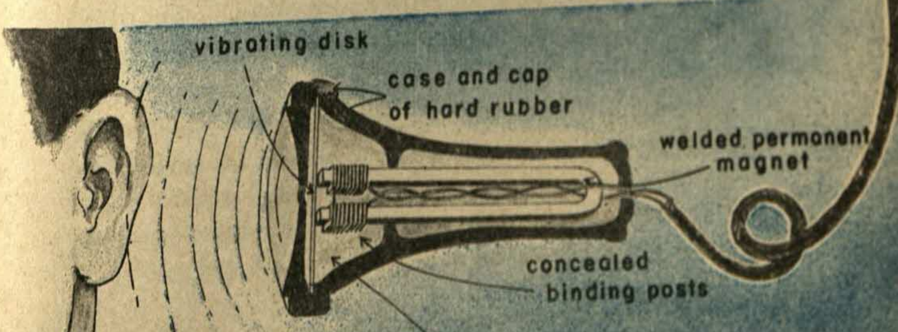
There were others who added to the telephone to make it what it is today. Edison and Blake devised a more efficient mouthpiece. George W. Coy made the first switchboard for connecting subscribers with each other. Strowger and Keith then devised the automatic switchboard and dial telephone which are rapidly doing away with telephone connections made by hand. Carty devised methods for eliminating stray noises that played over telephone circuits night and day, and Pupin invented the "loading coil" with which long-distance telephoning became practical and cheap enough for everybody to use. Recently, the vacuum tube has been introduced into the telephone, and radio has been called on to cooperate with the telephone in bridging vast distances across which wires cannot easily be stretched.



Essential parts of the telephone

Many of the essential parts of a telephone can be examined in your own telephone at home. Of course, it would not be wise to tamper with the instrument, for in the first place, it would interfere with your service, and in the second place, the instrument belongs to the telephone company and not to you. However, with the aid of careful observation and of the pictures shown on this page, you should be able to learn a good deal about it.

First, the *transmitter* or mouthpiece. This is a hard rubber horn which screws into a round base. Behind it is a metal disk or diaphragm. If you will examine the



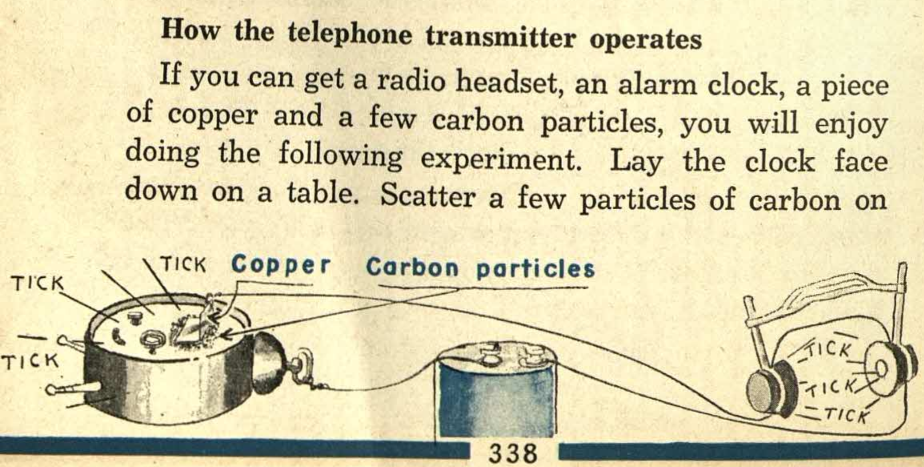
picture, you will see that any movement of this disk back and forth will push it against, or release its pressure upon, a number of carbon particles in a container right behind the disk.

Second, the *circuit*. This includes a source of current at the exchange and conducting wires from the source to your instrument and back to the source. You will notice that the hook or button on which the receiver rests moves up when the receiver is removed. When the hook is kept down, the bell-ringing circuit is ready to operate and the speaking circuit is broken. When the hook is lifted, the ringing circuit is broken and the speaking circuit is ready to operate.

Third, the *receiver*. Since a radio headset is really two telephone receivers attached to each other, you may find it worth while to examine one of these. Unscrew the cap of one of the radio receivers. You will find an iron disk, which is attracted by a permanent horseshoe magnet. Around the ends of this magnet are wound two coils of wire. The coils are connected and the two remaining ends are brought out at the rear of the receiver; in a telephone they lead to the telephone circuit.

How the telephone transmitter operates

If you can get a radio headset, an alarm clock, a piece of copper and a few carbon particles, you will enjoy doing the following experiment. Lay the clock face down on a table. Scatter a few particles of carbon on



the metal frame of the clock. You can get carbon particles by cracking up a carbon rod from an old dry cell. Now lay a small square of copper over the particles. Connect one wire with the copper and another with the metal frame of the clock, and stretch these wires to another room where the ends can be connected with a radio headset. Connect a dry cell in the circuit. If you adjust the copper over the particles very carefully, you will hear the clock ticking in the radio headset.

In the experiment above you have really made a telephone transmitter. The source of current (the cell) sends a direct current through the entire circuit. The flow is small because loosely scattered carbon particles offer great resistance. The tick of the clock, however, is a sound vibration and the metal frame of the clock acts as a disk which vibrates in accordance with the sound made. If a word had been spoken, this disk would have taken up a vibration corresponding to the word. Now, these vibrations cause varying pressures against the carbon particles. When the particles are compressed they offer less resistance to the flow of current. As the disk vibrates, the amount of current that flows in the circuit first increases, then decreases and continues to fluctuate. Therefore, this current must be a variable current since the pressure causing it is a variable one.

As we know, sound is caused by a vibration. Different sounds are caused by different vibrations. Thus, when you speak into a telephone transmitter, each sound you make causes the disk to vibrate in a special way. The carbon particles are then compressed in the same special way, causing the current to fluctuate in a manner which corresponds with the vibrations of the original sound.

It might all be summed up in this way. When you say "Hello" into a telephone transmitter, the disk vibrates in a "Hello" manner. The carbon particles are compressed in a "Hello" manner. This causes the direct current from the source to change into a "Hello" current.

How the telephone receiver operates

Let us continue the explanation begun in the paragraph above. What happens when a current varying in accordance with the word "Hello" reaches the receiver? The permanent magnet in the receiver is holding the iron disk in place. It is motionless. Should the strength of the magnet change in any way, this disk would move either closer to or farther from the magnet. Now comes the "Hello" current into the coils of the receiver. The coils become electromagnets and change the total magnetic strength which is attracting the iron disk. Furthermore, these changes are fluctuating in accordance with the word "Hello." The disk will then move back and forth in a "Hello" manner, reproducing the word "Hello" to the human ear held near it.

When Bell and Watson made their early experiments they did not use the carbon transmitter. They used the receiver both for talking and listening. If you want to see how this may be done, connect two radio headsets with two long wires. You do not need even a battery for this. You can hold one receiver to your ear and another to your mouth, while your friend, out in the hall, does the same with his headset. With such an arrangement you can talk to each other quite easily.

Things to Do

1. Make a large chart showing the structure of the human ear and of the human voice box.
2. Invite the school doctor to talk on the care of the ear.
3. If an automobile passes you with its horn sounding, the pitch seems to change. This effect is based on Doppler's principle. Report on this principle.
4. Borrow a good air pump from the physics teacher. Place an alarm clock inside a bell jar on a piece of sponge rubber. Pump out the air and note whether you can hear the clock ticking.
5. You can measure the speed of sound. Select a place where you can see several hundred feet and measure the distance carefully between two points. Borrow a stop watch and a pistol and blank cartridges from the physical director. Ask your teacher to take the pistol and stand at one end of your measured line. Stand at the other end of the line with the stop watch. Start the watch when the smoke appears as the pistol is fired, and stop it when the report is heard. You will then have the time that it takes the sound to travel a measured distance. The experiment should be done on a day with little wind and should be repeated.
6. Ask the school doctor to talk on the care of the eyes.
7. Obtain a smooth, shiny sheet of tin. Study the images in its mirrorlike surface when the metal is curved. Such mirrors are often used in amusement parks.
8. Make a report on the methods used by Professor Michelsen for measuring the speed of light.
9. Study the structure of a camera and compare its parts with those of the human eye.
10. Write an article for the school paper on, "Changes That the Telephone Has Made in Our Lives."

How Much Do I Remember?

Please do not write in the book.

I. 1. .... 2. .... 3. .... 4. .... 5. .... 6. .... 7. .... 8. .... 9. ....

(a) If ants can make loud sounds, write A in space 1. If Major Hingston studied ants, write C.

(b) If animals and birds can communicate with one another, write O in space 2. If insects make sounds as human beings do, write N.

(c) If John Tyndall developed the radio, write V in space 3. If sounds can pass through a vacuum, write S. If sounds can be produced by vibrating objects, write M.

(d) If air carries sounds better than water, write I in space 4. If vibrations are necessary in order that there shall be sound, write M. If the human vocal cords are located in the lungs, write A.

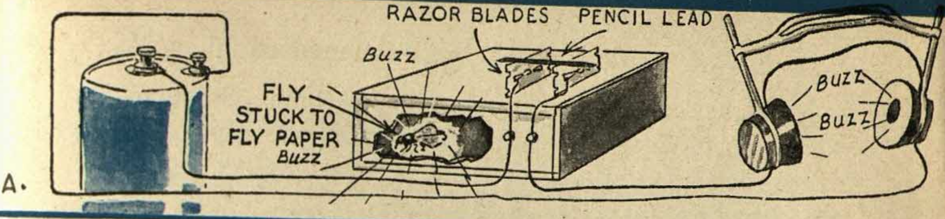
(e) If a rapidly vibrating object produces a high-pitched sound, write U in space 5. If the human ear can hear sounds when an object vibrates 100,000 times a second, write C. Otherwise, write T.

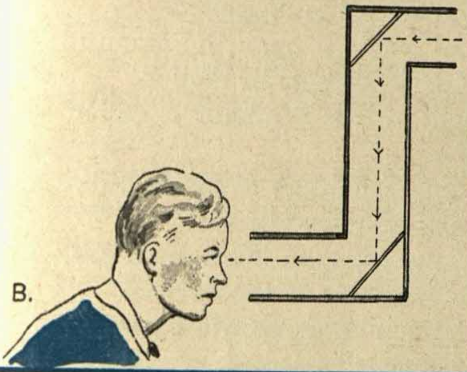
(f) If different musical instruments can be recognized by the pitch of their sounds, write F in space 6. If it would be possible to speak to another person on the moon, write S. Otherwise, write N.

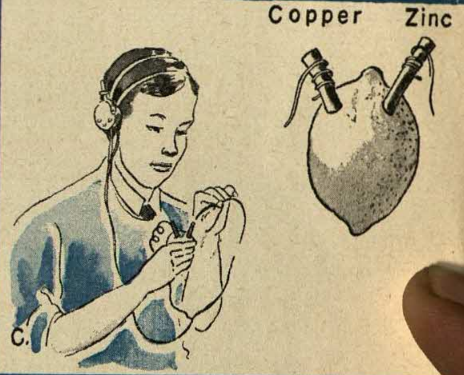
(g) If sounds travel 25,000 feet per second through air, write C in space 7. If the eardrum vibrates when sounds are heard, write I. If cats can see when there is no light, write T.

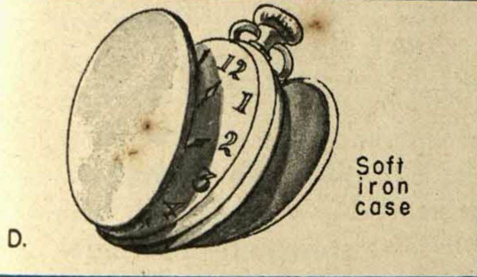
(h) If light usually travels in straight lines, write T in space 8. If light travels slower than sound, write P. If light is absorbed by shiny surfaces, write W.

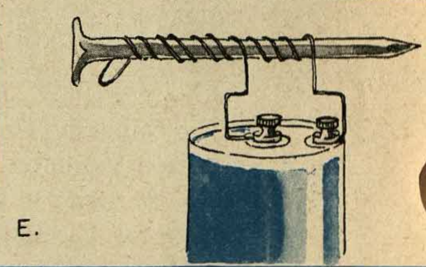
(i) If all rays of light pass straight through a lens, write D in space 9. If an object in water appears to be deeper than it actually is, write J. If the angles

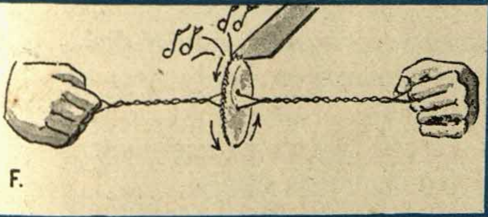


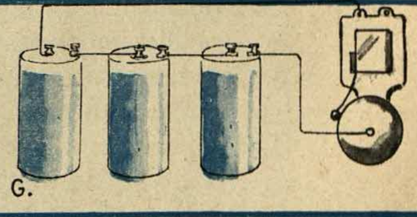












A. Telephoning the buzz of a fly. Try to do this experiment.
B. Make this simple periscope. C. Electricity from a lemon. Try this.
D. Of what use to the watch can the soft-iron case be?
E. How to wind a coil which cannot be magnetized. Explain this.
F. Make this Savart's wheel for studying the pitch of sounds.
G. What's wrong with this picture?

of incidence and reflection are equal, write Y.

II. The following statements are true. Some of the words have their letters badly jumbled. By arranging the letters properly you can get the correct statement. *Please do not write in the book.*

1. The vocal cords are located in the *nippewid.*
2. The *dunloess* of a sound depends upon the amount of air that the sounding body sets in motion.
3. The angle at which light strikes a mirror is called the angle of *decicinne.*
4. *Traifecnor* is the bending of light as it passes at an angle through transparent substances.
5. An image is formed on the *naiter* in the human eye.
6. *Mastgitasim* is due to distortion of the cornea.
7. *Tavol* discovered the principle of electric batteries.
8. *Cronleets* are negative particles found in all substances.
9. The *gratephel* was invented by Morse.
10. The movement of electrons makes an *lectrice trucern.*

III. The following statements are false. By changing the italicized word or words they can be made true. *Please do not write in the book.*

1. Sounds are produced by the *transmitter* of a telephone.
2. The telephone receiver contains a *hard rubber* disk.
3. The telephone transmitter causes a *steady* flow of current through the circuit.
4. A magnet hung on a thread will point *east-west.*
5. *Hardened steel* loses its magnetism easily.
6. *Professor Einstein* measured the speed of light.
7. Light is *reflected* when it passes through water.
8. A *concave* lens forms images which are upside down.
9. The lens of the human eye has a *fixed* shape.
10. *Farsightedness* may be caused by a lens which is too convex.

Atomic Energy for Better Health

A good part of the story of this book is about *energy*. You need energy for doing all the work that needs to be done in daily life. If you will examine again the pictures on page 227, you can see that there are several different forms of energy, all of them coming from the sun.

For a long time scientists were puzzled about the energy which comes from the sun. How is it produced? How does it get to us? How is it used and changed by living things on the earth? Will it ever be used up? In recent years, some of the answers have become a bit clearer. Most scientists now believe that the sun gets its energy from the *atoms* of which it is composed. The sun's energy is really *atomic energy*. Not until 1945, however, did scientists succeed in getting atoms on the earth to release their energy in a big way. We all know the story of the atomic bombs and how they helped to stop the Second World War.

Man-made atomic energy seems to bring dreadful fear to many people. Since newspapers and radio say so much about the bombs and the possibility of an even more powerful hydrogen atomic bomb, most of us may forget that atomic energy can help build a happier and healthier world. Better understanding and not fear can do this. We fear fire when it gets out of control, but we have learned how to control it and to use it in running engines, cooking food and heating homes.

Of course, atomic energy can be used for heat and light and for transportation and communication. But even more interesting is the fact that scientists are using atomic energy to find out more about how plants and animals grow and what really is happening inside their bodies. Atomic energy is helping doctors to understand better the workings of the human body, to track down certain of its diseases, and to find cures for some of them. There is much promise that atomic energy will bring us all better health and longer, happier lives.

How is atomic energy used in studying the bodies of plants and animals?

The scientist selects a healthy plant and places it in bright sunlight. Then he adjusts a small instrument, called a Geiger counter, so that it is close to one of the leaves. Wires lead from the instrument to a cabinet which resembles a table model radio. From time to time one hears a clicking sound, like static, coming from the loud-speaker.

After writing down the time in his notebook, the scientist pours a small amount of liquid on the earth at the base of the plant. Two hours go by. Suddenly the clicks become louder and faster. Again the scientist records the time.

What has happened? What made the Geiger counter next to the leaf suddenly respond with a greater number of clicks? The scientist would answer by saying that the liquid which watered the plant had contained *radioactive atoms*. These atoms were absorbed by the roots. Then they passed upward through the stem to the leaves. There the radioactive atoms operated the Geiger counter. Thus he now knows that it takes about two hours for materials to pass from the root of this plant to its leaves.

Through similar experiments, scientists are learning more about the way fertilizers in the soil are used by plants and how the leaves of plants manufacture sugars and starches out of carbon dioxide and water in the presence of chlorophyll and sunshine.

In another laboratory, a scientist is studying how a dog's body makes use of iron in the blood. It is known that the red blood cells need iron. The scientist explores the outside of the dog's body with the Geiger counter, placing the instrument near the dog's heart, arteries, veins, and near its liver and spleen. He notes the loudness and speed of the clicks. Then he gives the dog some food containing a small amount of a harmless liquid. In the liquid are some radioactive atoms of iron. At regular intervals, the scientist explores the outside of the dog's body as before. After a time, when the food has been digested and absorbed, the Geiger counter begins to respond with more clicking as the instrument passes over the dog's arteries. Eventually, most of the radioactive atoms end up in the liver and spleen. When the instrument is placed near these organs, the Geiger counter begins to click furiously.

From such experiments, scientists have learned that iron is absorbed by the blood only when needed. Most of the iron not found in the circulating red blood cells is stored in the liver and spleen.

What are radioactive atoms?

You have already learned something about atoms on pages 328 and 329, where we spoke only of the *electrons* inside of an atom. Every atom also contains a nucleus around which electrons revolve like the planets around the sun. See page 329. In the nucleus there are two other kinds of particles: *protons* and *neutrons.* The electrons are bits of negative electricity; the protons are bits of positive electricity; the neutrons are neither negative nor positive, but are neutral. Different kinds of atoms have different numbers of electrons, protons, and neutrons. The smallest and lightest atom, *hydrogen,* contains but one electron revolving about one proton. The uranium atom is one of the biggest and heaviest found on earth. Each uranium atom contains 92 electrons revolving about a nucleus in which there are 92 protons and from 143 to 146 neutrons.

In 1896, a scientist, Becquerel, placed a piece of mineral containing uranium on a photographic film which was wrapped in lightproof paper. On developing the film, he found on it a shadow picture of the piece of mineral. This was surprising, for no light could possibly go through the wrappings. After many experiments by Becquerel and others, they came to the conclusion that something must be coming out of the uranium atoms in the mineral which could pass through the wrappings of the film and affect it. This something must be a kind of energy similar to light but able to pass through things which light could not penetrate.

For some reason, not fully understood, an atom of uranium may break down, sending its electrons, protons, and neutrons flying out. Also, energy rays something like light, but much more penetrating, are sent out. Such an exploding atom is known as a radioactive atom.

How can atoms be made radioactive?

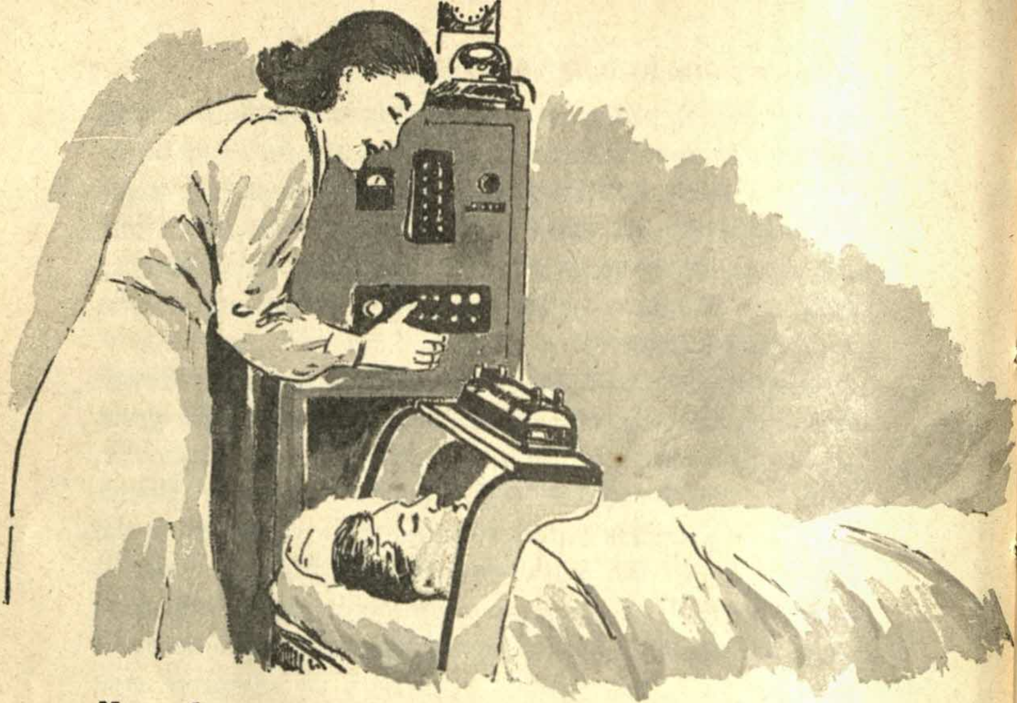
Very few of the more than 90 kinds of atoms on the earth are radioactive. Uranium, radium, and a few other elements have naturally radioactive atoms, but these elements are quite scarce and expensive. Within the last few years, however, scientists have discovered how to make the atoms of such common elements as carbon and iron radioactive.

When an atom of uranium or radium breaks down, electrons, protons, and neutrons fly out of it with great speed and force. If a bit of some other element is nearby, its atoms may be struck by the speeding particles. Sometimes the particles from the exploding atom enter the nucleus of an atom, thus making it bigger. Since it is not normal for such an atom to have an oversized nucleus, the atom may then explode; that is, it becomes radioactive.

During the last war, it was discovered that when blocks of uranium are piled up in a certain way, some of the uranium atoms split and give off large numbers of neutrons. When these neutrons strike other substances, they may disturb their nuclei and make them radioactive. This great structure of blocks of uranium is called an *atomic pile*. In an atomic pile, it is possible to make atoms of nearly all the common elements radioactive.

How are radioactive atoms used to learn more about the human body?

The human body is a very complicated structure with many separate parts. Physicians and other scientists



Nurse listens to clicks from Geiger counter held over patient's radioactive thyroid gland

have learned much about the human body and the way it works, but there are many things about it which are not known. If we knew more, we could give the body better care and enjoy better health. Radioactive atoms are the tool which is bringing us this greater knowledge. A good example of this is what we are learning about the body's blood.

In the blood there are billions of tiny red cells. The red color is due to the presence of iron. The iron comes from such foods as spinach and molasses. But how does the iron in food become a part of a red blood cell? What happens to the iron in the body while it is being made a part of a red blood cell? It was formerly impossible to follow a bit of iron about within the body and to learn what happened to it. It is easy to do so now, however, with the help of radioactive iron, which can be detected even when it is inside the body because of the rays which it gives off. A Geiger counter detects these rays and thus can follow the movements of the iron as it is carried about inside the body.

Similarly, other atoms such as carbon, nitrogen, phosphorus, and calcium can be made radioactive. By their use, scientists are now solving some of the problems which have puzzled them for a long time. They are learning much more about the way the human body works, both in good health and when diseased.

How are radioactive substances used to treat certain diseases?

Soon after radioactive substances were discovered, scientists began to wonder if they could not be used to destroy diseased tissues and so to cure illness? One very serious human disease is cancer. In this disease certain cells in the body grow much more rapidly than normal cells, producing a mass of diseased tissue. Often the cancer forms in some part of the body where the diseased tissue cannot be safely removed. Unless some way can be found to destroy the cancer, death may result.

It happens that many of the diseased cells in cancer are destroyed more easily by the rays from radioactive substances than are the normal, healthy cells. In many cases, cancers have been cured by using these rays. For a number of years, radium was the only known substance which gave off enough energy to make it useful in treating cancer, but radium is scarce and very expensive. Now that many common substances can easily be made radioactive, this form of treatment is used more widely.

One of the difficulties with the use of radium is that it is poisonous and cannot be taken into the body. When placed at the surface of the body, the rays from radium may not penetrate to diseased tissue located deep inside. This difficulty is overcome by making those substances radioactive which can safely be taken into the body. For example, there is a small organ located in the neck which is called the thyroid gland. This gland always contains a tiny amount of iodine. It is the only part of the body where this element is always found. Sometimes a cancer develops in the thyroid gland. When this happens, a tiny amount of radioactive iodine can be prepared. The person who has the diseased thyroid takes the radioactive iodine mixed in food or water. The blood then carries the iodine to the thyroid where it stays, giving off its energy among the diseased cells. Often such cancers are cured or relieved.

Of course, all diseases cannot be treated with radioactive substances. There is still much that is not known about these substances. They must be used with great care, for their rays can destroy healthy tissues if too large quantities are used. However, many diseases once thought incurable can now be treated successfully.

GLOSSARY

Here is a list of some of the words used in this book, together with their scientific meanings. The marks used to show the pronunciation are the ones found in standard dictionaries.

aileron (ā′lē-rŏn): a movable part of the back edge of an airplane wing used in making turns.
amphibian (ăm-fĭb′ĭ-*ă*n): an animal which lives both on land and in the water. Frogs and toads are amphibians.
antenna (ăn-tĕn′*ȧ*); plural, **antennae** (ăn-tĕn′ē): jointed feeler on the head of insects. Also, special wires used in radio broadcasting.
anther (ăn′thẽr): the part of a flower in which pollen is found.
Archeopteryx (är′kē̇-ŏp′tẽr-ĭks): earliest bird thus far found in fossils.
Archimedes (är′kĭ-mē′dēz): famous Greek scientist.
asteroid (ăs′tẽr-oid): one of the many tiny planets found between the orbits of Mars and Jupiter.
astigmatism (*ȧ*-stĭg′m*ȧ*-tĭz’m): a common defect of the human eye.
astronomer (*ă*s-trŏn′ō̇-mẽr): a scientist who makes a study of the heavenly bodies.

Bernoulli (bĕr′no͞o′yē′): famous Swiss scientist and mathematician.
bryophyllum (brī′ō̇-fĭl′*ŭ*m): a common house plant.
buoyancy (bo͞o′y*ă*n-sĭ): upward push of liquids on immersed objects.

calyx (kā′lĭks): the outer part of a flower.
centrifugal force (sĕn-trĭf′ū̇-g*ă*l): the outward force exerted by an object moving in a curved path.
chamois (shăm′ĭ): a small antelope living in the highest mountains of Europe and parts of Asia.
chronometer (krō̇-nŏm′ē̇-tẽr): a very accurate clock.
coleus (kō′lē̇-*ŭ*s): a common plant usually having varicolored leaves.
conglomerate (k*ŏ*n-glŏm′ẽr-ĭt): a sedimentary rock composed of grains and pebbles of various sizes.
conjugation (kŏn′jo͝o-gā′sh*ŭ*n): the process in which two simple living things exchange materials from their nuclei.
constellation (kŏn′st*ĕ*-lā′ sh*ŭ*n): a group of stars supposed to resemble a picture or a figure.
coquina (kō̇-kē′n*ȧ*): a soft, light-colored rock made up of shells and shell fragments.
cornea (kôr′nē̇-*ȧ*): the transparent covering over the front part of the eye.

corolla (kȯ-rŏl′*ȧ*): the part of a flower made up of petals which are usually bright-colored.

cotyledons (kŏt′ĭ-lē′d*ŭ*ns): the first leaves, or seed leaves, that are part of the embryo of a seed. In some plants the cotyledons form the first leaves to appear above ground.

Cro-Magnon (krō′mȧ′nyôn′): a race of men that once lived in Europe.

crustacean (krŭs-tā′sh*ă*n): an animal with a horny covering. Crabs, lobsters and shrimps are crustaceans.

dicotyledon (dī-kŏt′ĭ-lē′d*ŭ*n): a plant having seeds with two cotyledons, such as beans and peas.

Diesel (dē′z*ĕ*l): a German who invented the internal combustion engine which bears his name.

dinosaur (dī′nȯ-sôr): a kind of reptile which was once very common.

embryo (ĕm′brĭ-ō): the young plant enclosed in a seed.

endosperm (ĕn′dȯ-spûrm): food storage tissue which surrounds the embryo in a seed or lies between the embryo and seed coat.

fission (fĭsh′*ŭ*n): the division of one cell into two.

fluorescence (flo͞o′ō-rĕs′*ĕ*ns): property of a substance enabling it to receive light of one wave length and to give off light of a different wave length.

forsythia (fôr-sĭth′ĭ-*ȧ*): a shrub which blooms early in spring.

galaxy (găl′*ă*k-sĭ): a huge cluster of stars. The Milky Way is the galaxy of which the solar system is a part.

geologist (jē̇-ŏl′ō-jĭst): a scientist who studies the earth and the changes which it undergoes.

gneiss (nīs): a metamorphic rock made from granite.

gyrocompass (jī′rȯ-kŭm′p*ȧ*s): a device which indicates direction by use of a gyroscope.

gyroscope (jī′rȯ-skōp): a wheel with a heavy rim so mounted that it is free to turn in two or more directions.

Heidelberg Man (hī′d*ĕ*l-bûrg): an early race of men. The jawbone of one of these men was found near the city of Heidelberg, Germany.

hydraulic (hī-drô′lĭk): pertaining to the behavior of liquids.

hypothesis (hī-pŏth′ė-sĭs): an explanation which has not been proved but which seems reasonable.

igneous (ĭg′nė-*ŭ*s): produced by the action of great heat.

inertia (ĭn-ûr′shĭ-*ȧ*): the tendency of an object to remain in the same condition of motion or of rest.

infrared rays (ĭn′fr*ȧ*-rĕd′): radiation from heated objects which can be felt by the skin as heat.
invertebrate (ĭn-vûr′tê-brât): an animal without a backbone.

Krakatoa (krä′kä-tō′ä): island and volcano near Java. Its volcanic explosion was the most violent of modern times.

larynx (lăr′ĭngks): the upper end of the windpipe, containing the vocal cords; often called the Adam's apple.
lava (lä′v*ȧ*): melted rock that comes from a volcano.
legume (lĕg′ūm): kind of plants, such as peas and beans.
liverwort (lĭv′ĕr-wûrt′): a kind of plant related to mosses.
loess (lō′ĕs): a kind of soil which has been deposited by the wind.

marmot (mär′m*ŭ*t): a burrowing mammal such as the woodchuck.
meridian (m*ĕ*-rĭd′ĭ*ă*n): imaginary lines on the earth's surface, passing through the poles. They are often called lines of longitude.
metamorphic (mĕt′*ȧ*-môr′fĭk): pertaining to rocks which have been changed by the action of heat, pressure or other factors.
metamorphosis (mĕt′*ȧ*-môr′fô-sĭs): any change in the form of an animal or a plant from one stage of development to another; e.g., caterpillars change into butterflies.
meteor (mē′tê-ēr): small bodies which become luminous as they plunge into the earth's atmosphere from space; often called "shooting stars."
molecule (mŏl′ê-kūl): the smallest part of a substance which has all the chemical properties of the substance.
monocotyledon (mŏn′ô-kŏt′*ĭ*-lē′d*ŭ*n): a plant which has seeds with one cotyledon.

narcissus (när-sĭs′*ŭ*s): a flowering plant grown from a bulb.
Neanderthal (nâ-än′dēr-täl′): the name of an early race of men.
nucleus (nū′klê-*ŭ*s): a special part of the protoplasm of a cell.

obsidian (*ŏ*b-sĭd′ĭ-*ă*n): an igneous rock which is glassy in appearance.
orangoutang (ô-răng′o͞o-tăng′): a large, manlike ape found in Borneo and Sumatra.
ovary (ō′v*ȧ*-rĭ): the base of a pistil where ovules are produced.
ovule((ō′vūl): the body which becomes a seed after the egg is fertilized.

penguin (pĕn′gwĭn): a swimming bird found in the Antarctic.
penumbra (pê-nŭm′br*ȧ*): the partly lighted portion of a shadow.
photoelectric (fō′tô-ê-lĕc′trĭk): pertaining to the production of electricity by the action of light on a suitable substance.

pistil (pĭs′tĭl): the part of a plant in which the ovules are located.
pollination (pŏl′ĭ-nā′shŭn): the transfer of pollen from the anther to the stigma of a flower.
porphyry (pôr′fĭ-rĭ): a rock consisting of large crystals surrounded by smaller crystals.
pumice (pŭm′ĭs): a volcanic rock that is so full of little cavities that it is very light.

quartz (kwôrts): a very common mineral. Good crystals of quartz are clear and six-sided.

radiation (rā′dĭ-ā′shŭn): energy which passes through space. Light and infrared rays are radiations.
regeneration (rē-jĕn′ēr-ā′shŭn): the replacement of body parts lost through injury.
retina (rĕt′ĭ-nȧ): the layer at the back of the eyeball on which images are formed.
rhizome (rī′zōm): an underground stem which resembles a root.

sal ammoniac (săl′ ă-mō′nĭ-ăk): a substance used in dry cells.
sansevieria (săn′sė-vĭ-ē′rĭ-ȧ): a common house plant.
sedimentary rock (sĕd′ĭ-mĕn′tȧ-rĭ): rock formed from sediments which have become cemented together.
sextant (sĕks′tănt): instrument to measure latitude and longitude.
stamen (stā′mĕn): the part of a flower which produces the pollen. The anther is at the top of the stamen.
stigma (stĭg′mȧ): the top of the pistil, which receives the pollen.
stratosphere (străt′ō-sfēr): the upper part of the atmosphere.

translucent (trăns-lū′sĕnt): a material through which light will pass but through which objects cannot be seen clearly is translucent.
trilobite (trī′lō-bīt): an animal, once very numerous; now found only as a fossil. It was related to modern insects and crustaceans.

ultraviolet rays (ŭl′trȧ-vī′ō-lĕt): a radiation which may cause severe sunburn but which is beneficial in small amounts.
umbra (ŭm′brȧ): the totally dark part of a shadow.
uranium (ū-rā′nĭ-ŭm): one of the 92 chemical elements. It slowly breaks down, finally producing lead.

yucca (yŭk′ȧ): a plant bearing a large cluster of flowers which can be pollinated only by a certain kind of moth.

INDEX

Age of Fishes, 92; of Reptiles, 93
Air brake, 287
Airplanes, 218, 243, 272, 278–284
Air travel, 281–284
Alaska Highway, 247–248
Algae, 91, 156–157
Aluminum, 121
American Museum of Natural History, 87
Amphibia, 148–149, 171–172
Animals
  and plants, 215–216
  change earth's surface, 61–62
  communication of, 291–293
  conservation of, 152
  food of young, 176
  fresh water, 131–132
  land, 132–133, 135–136
  marine, 91, 131, 133–135
  number of offspring, 146–150
  overcome resistances, 238
Annuals, 143–144
Antimony, 122
Ants, 291–292
Archimedes, 198, 200–201, 262
Asteroids, 12
Astronomers, 12
Atomic energy and health, 345–352
Atomic pile, 349
Atoms, 328–331, 345
Automatic pilot, 272–273
Automobile, 244–245, 257–258
Automobile accidents, 252–255

Bacteria, 91, 136, 143–144, 156–157
Balloons, 273–275
Becquerel, 348
Bedrock, 99
Bell, Alexander Graham, 334–336, 340
Bernoulli, 280
Bicycle, 209–210
Biennials, 143–144
Birds, 135–136, 149, 171, 173–175
Block and tackle, 206
Boats, 263–266, 268–270
Budding, 157–158, 170
Bulbs, 154, 159
Buoyancy, 261–263, 273–274

Cancer, 351–352
Carbon dioxide, 62
Cartesian diver, 285
Centrifugal force, 193–194
Chamberlin, T. C., 20
Chemical elements, 116–118
Chickens, 174–175
Chromium, 122
Chronometer, 268
Clay, 74–75
Coal Age, 92–95
Comets, 18
Communication, 291–293, 331–340
Concrete, 82
Conglomerate, 75
Conjugation, 169
Constellations, 21
Continuity of life, 127–180
Copper, 117, 121
Coquina, 76
Cotyledons, 164–165
Cro-Magnon Man, 96
Crystals, 70–74, 113, 114, 116
Cuttings, 160

Darwin, Charles, 98–99
Density, 262–264, 309–310
Dicotyledons, 164
Diesel engines, 221, 269
Dinosaurs, 93
Dirigibles, 275
Diseases, 351–352
Distance to stars, 312
Doppler's Principle, 341
Dust Bowl, 108, 110

Ear, 303–305
Earth
  age of, 90
  appearance of man on, 95–96
  cause of day and night, 25–26
  changed by living things, 61–62
  changes in life on, 90–96
  facts about, 11
  interior of, 67
  like a magnet, 323
  mountain-forming on, 62–67
  neighbors of, 9–12
  pressure and temperature of interior, 77

- time, 26–29
- weathering and erosion of, 54–62
- Earthquakes, 64, 65, 67
- Earthshine, 32
- Earthworms, 97–99, 170
- Eclipses, 32–34, 45–46
- Edison, 336
- Eels, 166–167
- Electric eye, 35–37
- Electricity, 322–340
- Electric motor, 221–222
- Electromagnet, 331, 333, 340
- Electrons, 329–331, 347, 348
- Electron Theory, 328–331
- Embryo, 164, 165
- Energy, 35–44, 215, 222–228, 233–288, 345–352
- Erosion, 60–61, 108–110
- Explosives, 242
- Eye, 320–321

- Fertilization, 164, 171
- Fish, 146–147, 171
- Fission, 157, 169
- Flowers, 161–163
- Fluorescence, 115
- Force, 216
- Force of gravitation, 194
- Fossils, 84–90, 92–96
- Franklin, Benjamin, 326
- Frasch, Herman, 111–112
- Friction, 194–197, 201, 216, 237–238, 249–252, 266
- Fruit, 164
- Fuels, 120, 220–221, 241–244
- Fungi, 147, 158–159

- Galaxy, 21
- Galileo, 7–9
- Galvani, 326, 329
- Gas engine, 221, 243–245, 257
- Gears, 210–211
- Geiger counter, 346–347, 350–351
- Germination, 164–165
- Glacier, 58–60, 75, 78–79, 99
- Glider, 276, 278, 280
- Gneiss, 77
- Gold, 120
- Granite, 73, 77, 80
- Gravel, 75
- Gravity, 13–14, 29, 185–189, 200–201, 210, 216, 218, 237
- Greenwich time, 268
- Guinea pig, 175
- Gun, explosive force in, 242
- Gyrocompass, 271–272
- Gyroscope, 271–273

- Halley's Comet, 18
- Harvest Moon, 49
- Heidelberg Man, 95
- Helicopter, 282
- Helium, 274
- Henry, Joseph, 331
- Highways, 252–255
- Hoover, or Boulder, Dam, 236–237
- Hormones, root, 160
- Humus, 104–105
- Hydrogen atomic bomb, 345
- Hydrogen gas, 274
- Hypotheses, 20

- Iceland Spar, 115–116
- Inclined plane, 211–212
- Indians, 68–70, 129, 139–140
- Inertia, 12–14, 189–193, 201, 216, 237, 252
- Infrared rays, 41–44
- Insects, 148
- Instinct, 167
- Interdependence, of plants and animals, 136–138
- Invertebrates, 92, 132
- Iron ore, 119, 120

- Java Man, 95
- Jet-propelled airplanes, 243
- Jupiter, 8–12

- Kites, 275–277, 280, 326
- Krakatoa, 53–54, 66

- Latitude, 266–268
- Leaves, plants produced from, 160–161
- Legumes, 136
- Lens, 318–321
- Lever, 201–205
- Lichens, 136
- Life cycle, 143, 144
- Life expectancy, 146
- Life span, 143–146
- Light, 40–44, 306–321
- Light-year, 312
- Limestone, 76–77, 81
- Living things
  - adaptations, 133–138
  - conservation of, 152
  - distribution of, 130–133

  man's dependence on, 150–152
  number of offspring, 146–150
Location, determined by latitude and longitude, 266–268
Locomotive, 255–256
Loess, 108
Longitude, 266–268

Machine age, 201
Machines, simple, 198–213, 249
Magnets, 322–325
Mammals, 93, 150, 175–176
Man
  adaptation to surroundings, 138–141
  ancient men, 95–96
  and work, 217
  life span, 146
  overcomes resistances, 239
Manganese, 122
Marble, 77, 80–81
Mars, 9–12, 19
Mean solar time, 27
Mercury, 9, 11, 18, 122
Metals, 117
Meteorites, 18
Meteors, 17–18
Michelsen, Professor, 341
Migration, 166–167
Milky Way, 7, 21
Minerals, 111–123
Mirrors, control light, 312–313
Molds, 158–159
Molecules, 37
Monocotyledons, 164
Montgolfier brothers, 273–274
Moon, 7, 11–12, 22–24, 29–34, 45–46, 187, 300
Morse Code, 334
Morse, Samuel, 331–334
Mosquitoes and disease, 259–260
Moulton, F. R., 20
Mountains, 62–65

Neanderthal Man, 95–96
Nebulæ, 21
Neptune, 10–11
Neutrons, 329, 348
Newton, Sir Isaac, 13, 194
Newton's Law of Gravitation, 186–187
Nickel, 122
Nonmetals, 117–118
Nucleus
  of atom, 329, 348
  of plant, 163, 164

Obsidian, 73
Ocean liners, 269–270
Opossum, 175
Ores, 118–122
Oxygen, 117
Oyster beds, 170

Pacific Ocean
  earthquakes around, 65
  volcanoes in, 53
Panama Canal, 259–261
Paramecium, 168–169
Parasites, 133, 169
Parental care, 150, 173, 176
Peking Man, 95
Perennials, 143–145, 153
Periscope, 343
Petrified wood, 86
Photoelectric cell, 35–37
Piltdown Man, 95
Pitch, 296–300
Planets, 9–14. 18–21
Plants
  adaptations, 136–137
  and atomic energy, 346–347
  change earth's surface, 61–62
  early, 88, 91, 94
  fresh-water, 131–132
  land, 133
  marine, 91, 133–134
  needs of, 104–108
  offspring of, 146–147
  reproduction of, 153–165
Plastics, 123
Pluto, 10–11
Pollination, 136–137, 162–163
Porphyry, 73–74
Portland cement, 81–82
Prime meridian, 266
Protococcus, 156–157
Protons, 329, 348
Protozoa, 168–169
Puffballs, 158–159
Pulleys, 205–207
Pumice, 73
Pupin, 336
Pushes and pulls, 183–213

Quartz, 113–115

Radio, 322, 336

Radioactive atoms, 346–352
Radioactive iodine, 352
Radioactive iron, 347, 350–351
Radium, 349, 352
Railroads, 255–258
Redwood, 144
Reflection, Law of, 313
Refraction, 315
Regeneration, 170
Reproduction, 143–180
Reptiles, 93, 149, 172–173
Resistance, 237–239
Rocket, 242–243
Rock cycle, 78–79
Rocks, 68–96
Rootstock, 159
Runners, 159

Sailing ships, 266
Salmon, 143, 167
Salt, 118–119, 121
Salt-water aquarium, 178
Sand, 75
Sand dunes, 61
Sandblast, 240
Sandstone, 75, 81
Satellites, 11–12
Saturn, 10–11
Savart's wheel, 343
Scientific principles, 230
Screw, 213
Seeds, 161, 164–165
Seismograph, 124
Sequoia, 142
Sextant, 267–268
Shad, 167
Shale, 75
Sight, adjusted to light, 308–309
Sinkholes, 60
Slate, 77
Soil, 97–110
Solar system, 5–50
Sound, 293–305
Speaking and hearing, 291–305
Speed of light, 311–312
Sperry, Elmer A., 271
Sponges, 170
Spores, 158–159, 169
Standard time, 28–29
Starfish, 131, 134, 170
Stars, 7–9, 12, 14–15, 21, 225–226
    distance to, 312
Steam engine, 201, 221, 245–246, 255–257, 268–270
Steam turbine, 269–270
Stephenson, 255
Stone Age, 69–70
Submarine, 285
Subsoil, 99
Sulphur, 111–112, 118, 121–122
Sun, 9, 13–17, 31, 35–46, 345
Sunburn, 40, 42
Sunspots, 16, 43

Telegraph, 322, 331–334
Telephone, 322, 334–340
Telescope, 47
Television, 322
Termites, 137
Thyroid gland, 350, 352
Tides, 29–31
Tilefish, 152
Time, 26–29
Tin ore, 120, 122
Top, gyroscopic, 271
Transmitter, 337–340
Trilobites, 91
Tungsten, 122
Tyndall, John, 293–294

Ultraviolet rays, 40–44, 115
Underground stems, 159
United States Fish and Wildlife Service, 152
Uranium, 348, 349
Uranus, 10–11

Vacuum tube, 336
Venus, 9, 11, 19
Vertebrates, 92, 132
Vocal cords, 296, 300
Volcanoes, 53–54, 66–67
Volta, 326–329

Water, power of, to move objects, 241
Water transportation, 265–266
Watson, 335–336, 340
Weather stations, 275
Weathering, 101
Wedge, 213
Weight, 187–188
Wheel, 197, 248–251
Wheel and axle, 208–211
Windmills, 220, 240
Work, 214–223, 240–246

Yeast, 157–158
Yucca, 136–137